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of

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Devoted to Science and the Mechanic Arts

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THE MEASUREMENT OF TRANSMISSION-FACTOR.

BY

M. LUCKIESH and L. L. MELLOR.*

Nela Research Laboratory, National Lamp Works, General Electric Company.

INTRODUCTION.

In a previous paper one of the authors[1] pointed out the difficulties in the measurement of reflection-factor and showed that, notwithstanding the nonchalance with which values of reflection-factors are usually presented, such measurements are generally difficult to make and even more difficult to express with meaning. Except in the ideal cases of perfectly specular and diffuse reflection, the reflecting characteristics of media cannot be expressed simply by means of mathematical relations. Furthermore, the determination of the reflection-factor cannot be attained by measuring a single quantity, except in the two ideal cases already noted, unless the method involves integration. There are many factors, such as surface character of the medium, the distribution of brightness in the light-source and the character of the illumination, which so influence the reflection-factor that the latter cannot be taken as an invariable value for a given medium, except for the conditions under which it is determined. In the former paper the question of color, which includes such factors as the spectral character of the illuminant, the spectral transmission of the medium, and the

* Communicated by Mr. Luckiesh.

[1] Measurement of Reflection-Factor, M. Luckiesh, *Elec. Wld.*, May 19, 1917.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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method of photometry, was discussed. It was also stated that a similar general analysis was being prosecuted with respect to transmitting media. For further details and conclusions regarding the measurement of reflection-factor the reader should consult the former paper.

Most of the discussion of the measurement of reflection-factor applied equally well, with obvious modifications, to the determination of transmission-factor. The aims of the present work were to show the influence of various factors and to obtain a simple, practical method of measuring transmission-factor by the determination of a single quantity. Of course, it is obvious that the transmission-factor may be computed by mathematical integration for a given set of conditions if the transmission-characteristic curve is known, but this method is a tedious one and, in many cases of slightly diffusing or coarsely refracting media, it is not satisfactory. In order to conserve space many of the details will be omitted because the previous treatment[1] of this should suffice.

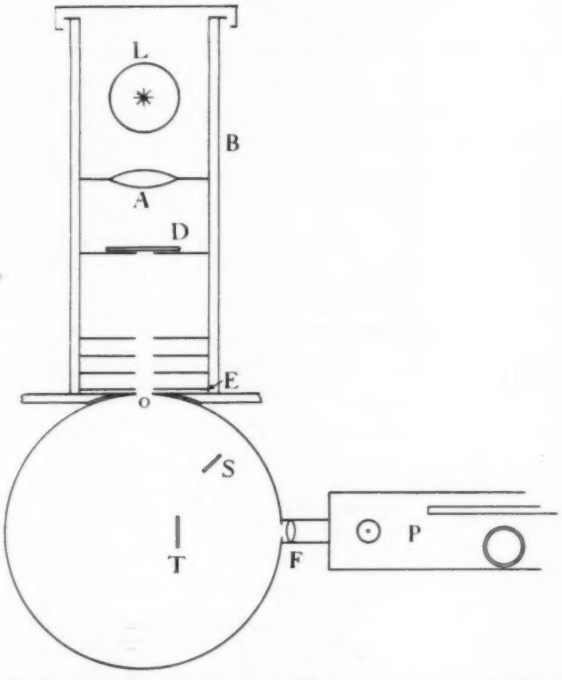
APPARATUS AND METHOD.

As already stated, one of the aims of this work was to devise a practical method and apparatus for determining transmission-factors which required the measurement of only a single quantity. For this reason an integrating method is necessary and, consequently, the sphere was chosen as a fundamental. A brass sphere, about 15 inches in diameter, was spun for this purpose. Inasmuch as the distribution of illumination is an important factor, it appeared best to choose types which could be readily described and reproduced. Two types were chosen, namely, a parallel beam of small cross-section, directed perpendicularly to the surface of the specimen under investigation, and diffused hemispherical illumination. These correspond, for example, to the direct light from the sun, and to the diffused light from an unobstructed, uniformly bright sky respectively. A Sharp-Millar photometer was used throughout the measurements, care being taken to operate within its best range.

Several variations in the apparatus were made in order to obtain comparative data which it was hoped would indicate a satisfactory method to be used eventually. These are shown in Figs. 1, 2, and 3.

In Fig. 1 the sphere is seen in relation to the photometer *P*, and the box *B* from which a directed beam of light was obtained. Over the opening, *O*, which was 7/8 inch in diameter, the specimens of transmitting media were placed. Just above the latter was a screen, *E*, covered with black velvet, and similar screens were placed above this one as indicated. The openings in these screens were about one inch in diameter. A sand-blasted glass

FIG. 1.

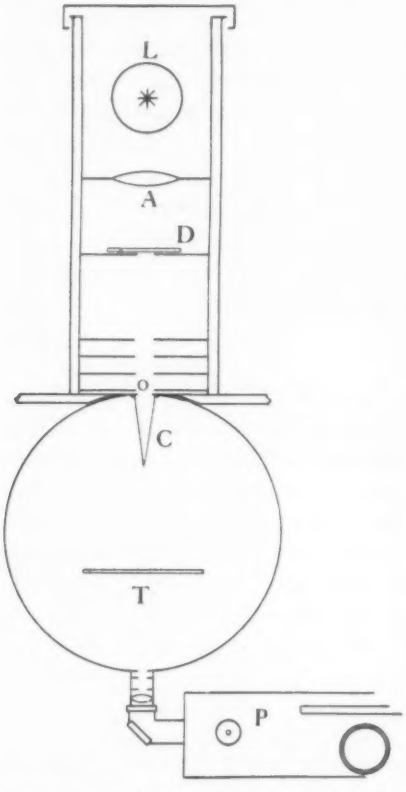


One arrangement of apparatus which yielded unsatisfactory results. See column 4 in the table.

was placed at *D*, a large lens at *A*, and a concentrated-filament tungsten lamp at *L*. The box was ventilated by means of light-traps and was painted black inside. The screens were covered with black velvet on both sides and the inner surface of the sphere was painted with a matt white paint as neutral in color as it could be conveniently made. The target, *T*, covered with the same kind of white paint, was placed perpendicular to the axis of the photometer and just outside the beam of light enter-

ing *O*. A small screen, *S*, was placed as shown to shield the photometer opening in the sphere from any rays directed toward it from *O*. A lens, *F*, in the photometer tube brought the target in focus for the eye. The elbow tube of the photometer was not used in this case. The various precautions common to pho-

FIG. 2.



Apparatus used for determining transmission-factors of specimens illuminated by a narrow beam of light directed perpendicularly to the surface of each specimen. See column 5 in the table.

tometric work were observed. As might be expected, spurious determinations of transmission-factor were obtained owing to the very asymmetrical distribution of brightness in the sphere with respect to the photometer axis. The aim was to determine the brightness of the target, *T*, when a specimen of transmitting media was over *O*, in terms of the brightness of *T* when no

specimen was over the opening, *O*. The procedure and results are discussed later.

Next it appeared desirable to obtain symmetry in the arrangement of the various parts by placing the photometer at the bottom of the sphere as shown in Fig. 2. A large target was then placed as shown at *T*. This received light indirectly as before. In the case of slightly diffusing media, *T* intercepted the beam and scattered it to various parts of the surface of the sphere. Thus the light which reached the lower side of *T* arrived by very indirect routes. Only a small portion in the centre of *T* was viewed in making observations. Systematic measurements were also made with this arrangement which will be discussed later. For certain reasons it appeared worth while to attempt to scatter the light immediately upon entering *O*. Of the various forms which could be easily made, a long narrow cone appeared satisfactory. This hollow cone was made of clear glass with an open base 1.5 inches in diameter and about 4 inches long. Its exterior surface was then very finely etched and it was fastened as indicated in Fig. 2. Measurements with and without the cone, *C*, were made.

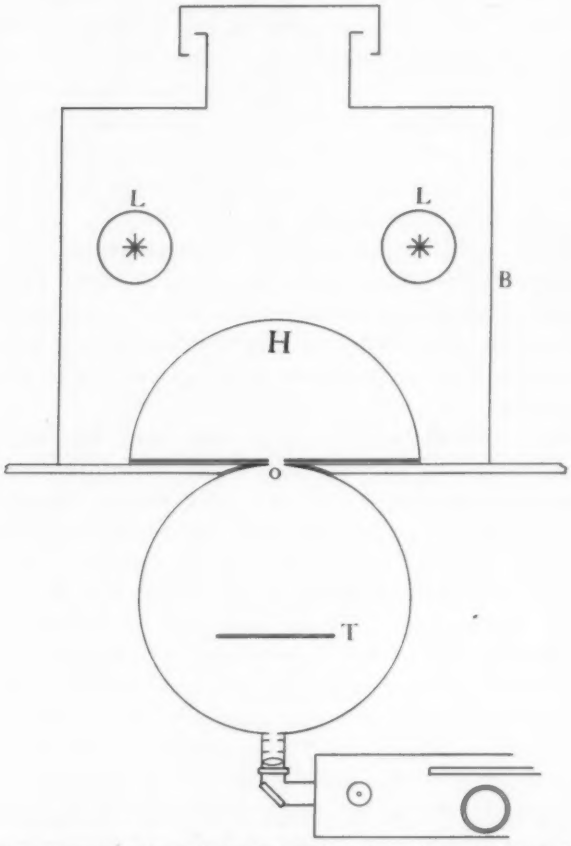
In Fig. 3 is shown the apparatus used for obtaining the transmission-factors for the same specimens illumined by diffused illumination. The sphere and photometer arrangement was the same as in Fig. 2, but the box supplying the parallel beam of light was replaced by the box, *B*, as shown. This was two feet square and was supplied with forced ventilation to keep the white inner surface from deteriorating owing to the excessive heating from the eight 200-watt tungsten lamps, *L*, used. A hemispherical bowl, *H*, of sand-blasted opal glass was placed symmetrically over the opening, *O*. This hemisphere was 16 inches in diameter. The aperture *O* was just even with the upper surface of the floor of the box *B* and was surrounded by black velvet. Upon this black velvet the specimen was placed and a thin velvet-covered screen 16 inches in diameter was placed over the specimen. The hole in this thin screen was one inch in diameter and was directly above *O*. Descriptions of minor mechanical details are omitted. By placing the eight lamps near the sides of the box and symmetrical with respect to the base of the hemisphere, by painting the inside of the box white, and by using a sand-blasted opal hemispherical bowl of moderate

density it is reasonable to assume a fairly uniform illumination of O from all possible directions.

PROCEDURE.

First, without any medium over the opening, O, a set of ten observations was made. The glass to be studied was then intro-

FIG. 3.

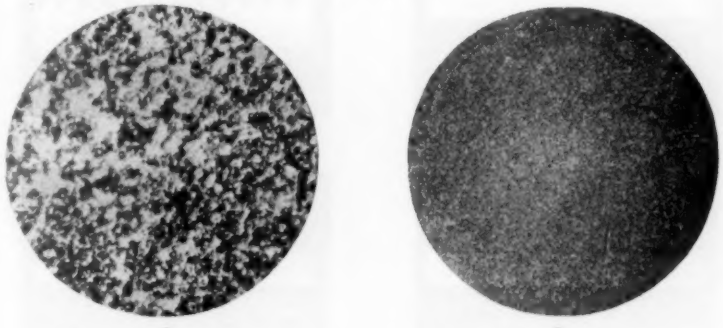


Apparatus used for determining transmission-factors of specimens for hemispherical illumination, that is, for thoroughly diffused light. See columns 6 and 7 in the table.

duced above O in contact with it and, with certain conditions of screening already noted, a set of ten observations was made. The specimen was removed and a set of observations was made similar to the first. Another set with the glass over O was made and finally another "clear" set. Therefore sets 1, 3, and 5 were

"clear" sets or, in other words, *O* was clear; sets 2 and 4 were made with the specimen of transmitting media over *O*. These five sets constituted a series and in the table all the individual values presented represent the mean from five or more series of five sets each, or each value represents 250 or more individual observations. The values obtained in each series were sufficiently consistent to inspire confidence in the results. The transmission-factor is computed from a single series by averaging the result of sets 2 and 4 and dividing this value by the mean of sets 1, 3, and 5. It is seen that the "clear" reading need be made only once, so that the transmission-factor thereafter would be obtained by determining the value of a single quantity. However,

FIG. 4.



5 7

Photomicrographs of a coarse sand-blasted surface of clear glass (5) and of an acid-etched surface of clear glass (7). Equal magnification.

it is a safer plan to interweave these "clear" observations as indicated in the foregoing.

SPECIMENS OF GLASS.

No. 5.—A thin sheet of clear glass, about 1/16 inch thick, sand-blasted on one side. A photomicrograph of its surface is shown in Fig. 4, contrasted with a photomicrograph of a very finely etched glass surface equally magnified. Various degrees of fineness may be obtained by means of the sand-blast. This specimen may be considered as fairly coarse.

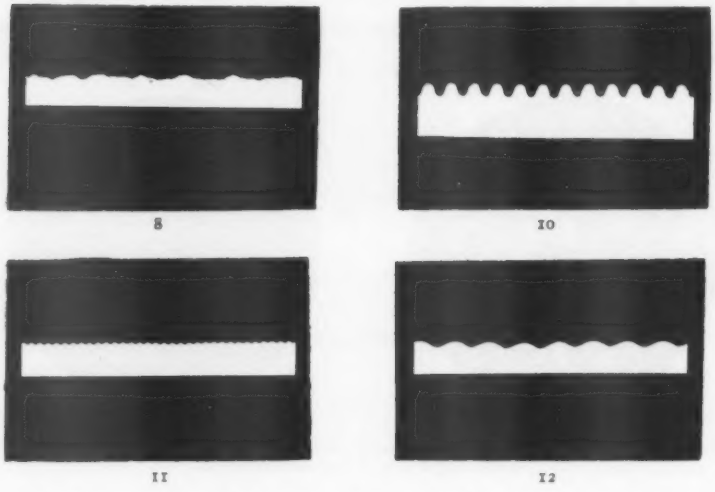
No. 6.—A thin sheet of ordinary clear glass about 1/16 inch thick.

No. 7.—A thin sheet of clear glass, about 1/16 inch thick, etched on one side very finely and uniformly with acid. A

photomicrograph of its surface is shown in Fig. 4, contrasted with one of No. 5.

No. 8.—A coarse pebbled glass, about 3/16 inch thick, with one side smooth. Photographs of its cross-section, of the coarseness of the pebbling, and of the character of the scattering of light from a very small light-source are shown in Figs. 5, 8, and 6 respectively. In Fig. 6 the scattering of light is shown for two cases, namely, when the rough and smooth sides faced the light-source respectively.

FIG. 5.



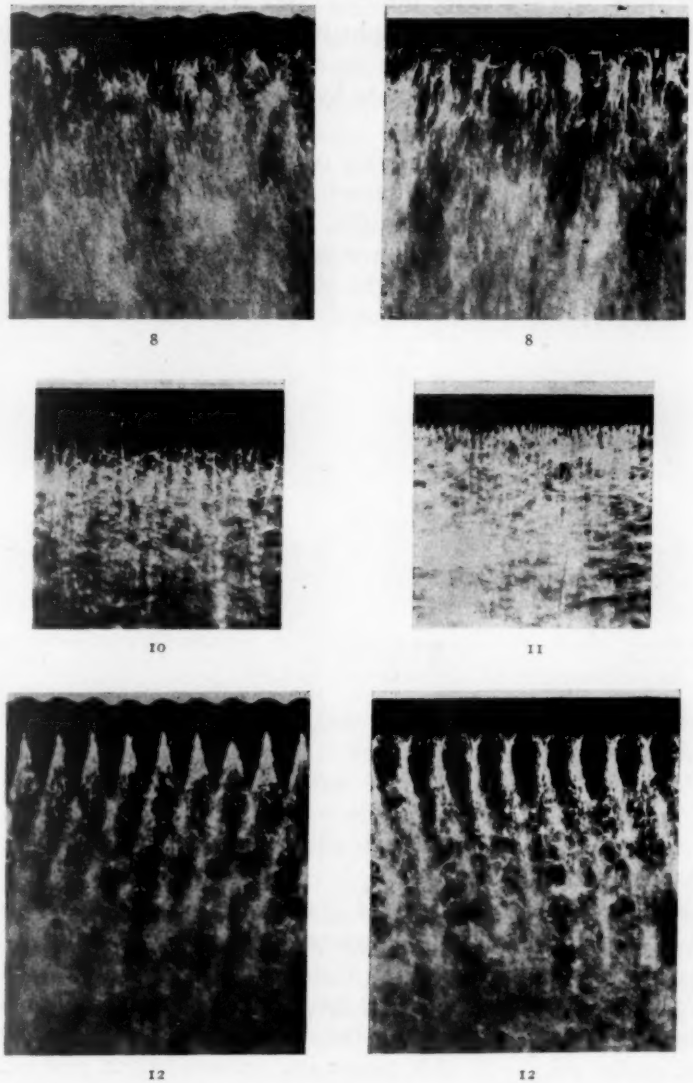
Full-size cross-sections of specimens of crystal glass, Nos. 8, 10, 11 and 12.

No. 10.—A clear glass about 5/16 inch thick, smooth on one side with about 8 ribs to the inch on the other side. The character of the ribs is shown in Fig 5. The character of the scattering of light from a small source of light is shown in Fig. 6 when the smooth side faced the light-source.

No. 11.—A clear glass, about 3/16 inch thick, smooth on one side with about 23 ribs to the inch on the other side. The character of the ribs is shown in Fig. 5, and the scattering of light from a small source of light is shown in Fig. 6 when the smooth side faced the light-source.

No. 12.—A clear glass, about 3/16 inch thick, smooth on one side with coarse, shallow, wavy ribs, about five to the inch,

FIG. 6.



Showing the scattering of light by specimens 8, 10, 11 and 12. For specimens 8 and 12 two cases are shown, namely that for the rough surface toward the light source (left-hand illustrations) and that for the smooth surface toward the source (right-hand).

on the other side. The character of the ribs and of the scattering of light from a small source of light are shown in Figs. 5 and 6 respectively. In the latter the two cases are shown.

The cross-section photographs in Fig. 5 were made by placing a smooth blackened edge in contact with a photographic emulsion and exposing the plate by means of a slight-source in a proper position.

With certain glasses an idea of surface character may be obtained by printing a photograph by direct contact (Fig. 8), using a very small source of light. If successive exposures are made as the glass and plate are separated more and more, an idea of the distribution of light in the space near the glass is obtained. If the source subtends a large solid angle at the

FIG. 7.

10*a* 10*b*

Showing different reflection-factors for specimen 10 depending upon the surface which faces the light-source. In *a* the ribs face the light-source; in *b* it has been reversed. This indicates also a difference in the transmission-factors. See table.

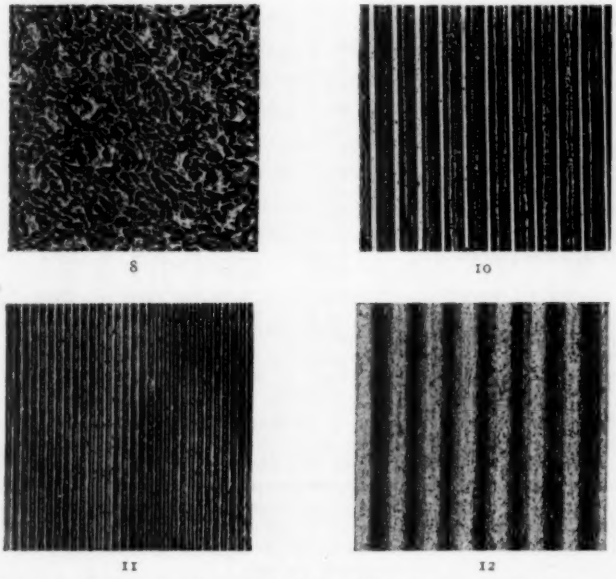
glass the surface character is not shown very well by contact printing and as a limiting case if the source is similar to an unobstructed overcast sky the surface character is almost, if not, entirely, obliterated. In the contact prints shown in Fig. 8 the rough side was in contact with the photographic plate in each case.

By placing the specimen of glass vertical with one edge in contact with a horizontal photographic plate and permitting light to pass through the specimen from a small source situated at some distance and just above the plane of the plate, a fairly accurate picture is obtained of the character of the scattering of light by the glass. By this means the scattered light just grazes the photographic plate and the many devious paths leave their records on the plate. Some photographs obtained in this manner are shown in Fig. 6.

These and many other effects may be recorded with ease without the use of a camera and the data revealed are interesting and show most of the characteristics of the glass quite well. If permanent records are not desired the same effects may be made visible to the eye by using diffusely reflecting and transmitting white media instead of photographic plates.

Of course, the appearance of a glass, which scatters light in a manner similar to these specimens, that is, not perfectly dif-

FIG. 8.



The prints were made from negatives obtained by placing the rough side of the specimens in contact with a photographic plate. They were illuminated by means of a small light-source.

fused, is of importance. This appearance for different conditions of illumination can best be recorded by visual observation or by photographing it with a camera.

In attempting to record certain characteristics of these glasses a small source of light has been used because the other extreme kind of source (hemispherical illumination) blots out most of the effects. Some experiments and photographs of these characteristics were made with sources subtending solid angles varying from hemispherical to zero. These results are interesting and useful, but not essential to this paper.

Transmission-Factors Obtained Under Various Conditions.

(See Note.)

Specimen.	Relation of ribs to photometer axis.	Side toward light source.	Results by various arrangements of apparatus.				Ratio (with cone) diffuse / direct
			Small perpendicular beam.		Hemispherical illumination.		
			Fig. 1 without cone.	Fig. 2 with cone.	Fig. 3 without cone.	Fig. 3 with cone.	
			(*Column 4*)	(*Column 5*)	(*Column 6*)	(*Column 7*)	(*Column 8*)
			per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
6	.....	.....	91.3	91.2	90.0	90.0	98.9
5	.....	Sand-blasted	91.7	78.3	71.1	70.2	89.7
5	.....	Smooth.....	87.4	73.9	70.9	69.5	94.0
7	.....	Etched.....	89.8	79.4	70.5	70.9	89.3
7	.....	Smooth.....	84.6	75.8	70.7	70.4	92.9
8	.....	Pebbled....	89.9	84.6	74.7	74.6	88.2
8	.....	Smooth.....	84.0	79.0	74.9	74.6	94.4
10	Perpendicular	Ribs (coarse)	119.7	76.6	61.5	61.7	80.5
10	Perpendicular	Smooth.....	69.5	51.5	61.8	61.6	119.6
10	Parallel.....	Ribs (coarse)	86.0	77.0	61.1	61.4	79.8
10	Parallel.....	Smooth.....	59.0	51.4	61.9	61.6	119.7
11	Perpendicular	Ribs (fine)..	94.9	85.8	76.0	79.3	92.4
11	Perpendicular	Smooth.....	91.3	79.0	76.0	79.1	100.1
11	Parallel.....	Ribs (fine)..	88.5	85.8	76.2	79.1	92.2
11	Parallel.....	Smooth.....	84.7	78.8	75.9	79.0	100.3
12	Perpendicular	Ribs (wavy)	94.4	88.4	79.6	82.2	92.9
12	Perpendicular	Smooth.....	96.7	86.0	79.9	82.1	95.5
12	Parallel.....	Ribs (wavy)	90.2	89.2	80.1	82.1	92.0
12	Parallel.....	Smooth.....	89.7	86.2	80.2	82.2	95.4

NOTE.—The values in column 4 (obtained with apparatus represented in Fig. 1) are of interest only in pointing out certain errors of the particular apparatus used in obtaining them. The values in columns 5 and 7 are considered to be satisfactory for the two types of illumination respectively. In the last column are to be found the ratios of the transmission-factor for perfectly diffused light (column 7) to that for a narrow pencil of light striking the specimen perpendicularly (column 5). Under the conditions of the experiments there is an uncertainty in the last figure given in the foregoing values.

RESULTS.

The results obtained with different arrangements of apparatus already described are presented in the table for certain representative specimens of glass which were elaborately studied. In this table the specimen number is given in the first column. In the second column the direction of the ribs is shown in relation to the axis of the Sharp-Millar photometer. In the third column is noted the position of the surfaces of the glass with respect to the source of light which illuminated it. In the next four columns transmission-factors are given in per cent., as determined under various conditions. The first column of values

is of interest merely in showing the magnitude of the error which may arise from extremely asymmetrical conditions of illumination inside the sphere with respect to certain essential parts of the apparatus. The values in this column should be ignored beyond this; that is, they are not to be considered as absolute values.

In columns 5 and 7 the values are shown for the two types of illumination, directed and hemispherical respectively, when the diffusing cone was in place. The use of this cone under the opening *O* appears to be justified by the theory of it, by certain tests, and by some of the results. It will be noted that the result for clear glass illuminated by the narrow beam is about what it should be, namely 92 per cent., when the cone was used. Two different cones were used, one etched only on its exterior, the other on both its exterior and interior. These were removed and replaced, not necessarily in exactly the same position, without noticeably affecting the results. In order to ascertain more definitely the propriety of using such a device as the diffusing cone some tests were made. The opening *O* was reduced to one-half inch in diameter and a narrow beam of light was projected through it perpendicularly. Photometric readings were then made with both cones which were employed in the work. These cones were in various positions, such as symmetrical with *O*, at one side, tilted, etc., and in all cases the photometric readings agreed to within the accuracy of the apparatus. From these results and general experience the authors believe that the adoption of such a slightly diffusing device is not open to objection in a small sphere used for the present purpose. It will be noted that a narrow cone of this kind scattters the light very well without sending an appreciable amount back through the opening, *O*, thus overcoming the errors which may attend an extreme lack of uniformity of brightness inside the sphere. It is recognized that a certain error is possible for the case of hemispherical illumination, owing to the appreciable thickness of the glass as compared to the diameter of the opening, *O*, but this is ordinarily negligible. It is of interest further to consider the effect of the cone in connection with the results obtained for the ribbed glasses by comparing columns 6 and 7.

In the last column is found the ratio of the transmission-factor for diffused (hemispherical) illumination to that for a

narrow beam of light, directed perpendicularly, as measured with the slightly diffusing cone in place. In other words, the last column represents the values in column 7 divided by those in column 5. It is seen, as was to be expected, that the transmission-factor is generally less for diffused light than for a narrow beam of light directed perpendicular to the surface of the specimen. It is easy to account for those values which are greater for diffused than for directed light, by the refraction and total reflection within the glasses, and by surface reflection.

The value of the transmission-factor for the clear glass, No. 6, is about what would be expected for the perpendicular beam of light. The loss of light in this case is almost entirely due to reflection at the two polished surfaces. This loss depends upon the refractive index of the glass and upon the angle of incidence of the light and was computed to be 92 per cent. The amount of light reflected by two polished surfaces of glass does not appreciably exceed 10 per cent. until the angle of incidence reaches the neighborhood of 60 degrees. When it is considered that, as the angle of incidence becomes greater than this angle, the subtended opening grows quite small, it is not surprising that the value of the transmission-factor for hemispherical illumination remains near 90 per cent. A rough computation yielded about 85 per cent. for this value. This difference may possibly be due to a lack of perfectly diffused illumination.

It is interesting to note that, for the case of a narrow perpendicular beam of light, the transmission-factor for the sand-blasted specimen, No. 5, is less when the smooth surface is toward the light. This was suspected by us from the viewpoint of total reflection inside the glass at the glass-air surfaces, but the authors are unaware of the fact having been noted before. When it is considered to act, in the favorable cases, similar to totally reflecting glass prisms, the difference in the values of the transmission-factor is easily accounted for. It should be noted that total reflection in glass prisms takes place at glass-air surfaces and not at air-glass surfaces. It is perhaps due chiefly to this that more light is reflected by a sand-blasted glass when the smooth surface is toward the light source than when the position of the surfaces is reversed. The difference in the transmission-factors for a beam of light passing the two ways through such a glass is the greater for the normal illumination; in fact,

it should be obvious that such differences decrease as the illumination becomes more diffused or, in other words, as the light-source subtends greater solid-angles. In agreement with the preceding it is seen for No. 5 in column 5 that the transmission-factor when the sand-blasted surface is toward the light-source, is about 78 per cent. When the glass is reversed in position—that is, when the smooth side is toward the source, this value decreases to about 74 per cent. This difference, according to the measurements, is quite entirely eliminated for diffused illumination. It is of interest to note this difference in the case of the other samples. It becomes quite apparent to the eye for such a specimen as No. 10 as shown in column 5 and also photographically in Fig. 7. The specimen was photographed under conditions which exemplified the effect indicated by the determined values of transmission-factor. The light source was a window at a distance and the camera was placed between the window and the specimen. The exposure and development of the plate was the same for both cases. In *a* the ribs faced the camera and in *b* the smooth side was toward the camera. This point is emphasized strongly for the reason that it is of practical value.

In the cases of the ribbed glasses, the measurements were made with the ribs perpendicular to the axis of the Sharp-Millar photometer and also parallel to this axis. These values show the difficulties which may arise from an extreme lack of symmetry in the distribution of illumination in the sphere with respect to the target *T*, and they give an idea of the consistency of these determinations of transmission-factor (columns 5, 6, and 7).

The values in the last column show that the transmission-factor depends, among other things, upon the character of the illumination, being in general less for light emitted by a light source subtending a large solid angle at a point on the glass surface than for light directed normally to the glass from sources subtending small solid angles.

Attention is again called to the spurious values in column 4. These values are useful in the investigation, but if the reader is interested in transmission-factors he should refer to columns 5 and 7.

As previously stated the question of color has been eliminated

entirely in this discussion, for the remarks in the previous paper apply equally well to the measurement of transmission-factor. In general it should be noted that the transmission-factor of a colored glass varies with the spectral character of the illuminant and that the different methods of photometry yield different results when the color-difference is appreciable.

SUMMARY.

An investigation has been made of various arrangements of apparatus designed for the determination of transmission-factor by the measurement of a single quantity. An integrating method has been studied, and under certain conditions appears to be satisfactory. The results appear satisfactory for practical purposes.

The transmission-factors have been obtained for several representative slightly diffusive glasses for two kinds of illumination; namely, (1) a narrow beam of light directed perpendicularly to the surface of the specimen, and (2) uniformly diffused light reaching the specimen from all directions above its plane. The latter may be known as hemispherical illumination. Some of these specimens may be described as coarsely refractive.

In general the transmission-factor is less for diffused (hemispherical) illumination than for a narrow beam of light directed perpendicularly.

It has been shown that the transmission-factor of such glasses as studied in this investigation depends upon the position of the glass with respect to the light-source for a narrow beam of light directed perpendicularly to the specimen. In other words, the transmission-factors are generally considerably greater when the rough surface faces the light-source than when the smooth side is toward it. This difference is very apparent visually in the case of ribbed glasses, but it has been found to exist even for so-called "frosted" or etched glasses.

Several simple photographic procedures have been carried out with the aim of representing certain characteristics of such glasses for which verbal description is unsatisfactory. These include the surface character, the cross-section, the appearance, and the scattering of light after passing through a specimen.

BIBLIOGRAPHY.

There is only a scanty literature on skylight glass, but various aspects of diffusing glass have been treated by others. The Transactions of the Illuminating Engineering Society contain many articles and discussions which should supply interesting material to those who may care to venture into the past literature on the general subject of transmitting media.

Dr. C. H. Sharp in his lecture in the I. E. S.—U. P. course in 1916 ("Illuminating Engineering Practice," p. 127)—briefly discussed the use of the integrating sphere for the measurement of the transmission factor of a diffusely transmitting medium.

Mr. E. J. Edwards (Trans. I. E. I., **9**, 1914, p. 1012), in a paper on "The Lighting of Rooms Through Translucent Glass Ceilings," presents the transmission factors of different types of glasses. He also discusses the important aspect of freedom from a spotted appearance when lighting units are installed above the skylight. In consideration of this point he presents the ratios of mounting height above the glass to the distance between units for the elimination of spotting for various types of glasses.

The Committee on Glare of the I. E. S., in one of its reports entitled "Diffusing Glassware" (Trans. I. E. S., **11**, 1916, p. 367), presented a discussion of certain diffusing characteristics. Dr. P. G. Nutting treated this aspect in a paper on "Reflection and Transmission of Light" (Trans. I. E. S., **7**, 1912, p. 616).

M. Luckiesh in two papers on "Diffusing Glassware" (*Electrical World*, **60**, 1912, p. 1040; **61**, 1913, 883) presented the transmission characteristics of a number of diffusely transmitting glasses.

A number of papers on illuminating glassware contain material of interest in connection with the problems treated in the present paper, of which the following are representative:

V. R. Lansingh: "Shades, Reflectors, and Diffusing Media," Vol. II, Lectures on Illuminating Engineering, Baltimore, 1910.

V. R. Lansingh: "Characteristics of Enclosing Glassware," Trans. I. E. S. Sept., 1913.

G. H. McCormack, A. J. Marshall, L. W. Young, and Bassett Jones: "Symposium of Illuminating Glassware," Trans. I. E. S. Sept. 1911.

W. F. Little: "Modern Lighting Accessories," 1916 Lecture Course of I. E. S. and U. P., "Illuminating Engineering Practice." p. 182. This paper contains a number of references.

NELA PARK, CLEVELAND, OHIO.
February, 1918.

Artillery and Small Arms for the United States Forces. H. O'HIGGINS. (*The Official Facts*. Committee on Public Information, Washington, D. C., September, 1918).—When we declared war, the military authorities of Great Britain and France offered to provide our expeditionary forces with big guns in order to save our ship tonnage from the burden of transporting heavy ordnance and to keep at a maximum production the ordnance works abroad. France and Great Britain had an adequate force of skilled workmen for making heavy ordnance and we had not. In this country all the factories that could make the large machine tools necessary for turning, boring and assembling big guns were already busy on contracts for the Allies. In order to prevent a confusion in Allied plans, to save ship tonnage, and to make a wise use of such arsenals and workmen as the Allies had, our War Department agreed to accept as much as possible of its first year's supply of guns abroad and to devote that year to developing its own big-gun industry.

The program has been carried out successfully. Our forces in Europe have had a sufficient supply of guns and ammunition purchased in Europe. Our men in the trenches have had the same heavy ordnance protection that the French and British troops have had. We have sent over some heavy artillery, to supplement the Allied supply, and we have developed our own designs, built our own factories, installed our machines and trained our own workmen for the manufacture of all sorts of big guns. We have spent five billion dollars on ordnance in our first year, and we are planning to spend twelve billion dollars in our second.

The complaint has been made that our ordnance bureau lost six months in vain efforts to improve on the perfect recoil mechanism of the famous French 75's. That is untrue. The charge is due apparently to the fact that we prepared designs for an American three-inch gun which was put into production before the models for the 75 arrived from France. We are making both guns, and our contracts call for the delivery of more than 3000 of them by January, 1919. After that date the 1917 model of the French 75 will be manufactured here at the rate of about 500 a month. Our own design of this gun, with the "split" carriage, is more flexible even than the French 75, and more deadly therefore to the enemy.

Of the six-inch sea-coast gun, our contracts provide for the delivery of 400 by January, 1919, and of 200 a month thereafter. Of the 155 millimeter howitzer, 1500 are to be delivered by January, 1919. Deliveries of the 240 millimeter howitzer are reaching 100 a month.

We are producing the light and heavy Brownings at the rate of about 5000 a week. We are turning out the new American rifle at the rate of 60,000 a week. Our automatic pistol, calibre 45, has already demonstrated its efficiency in close fighting. All these weapons are being produced in vast quantities, and our ordnance division has proved itself as resourceful as the men whom it has armed and as efficient as the weapons with which it has armed them.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.

BY

JOSHUA J. SKINNER, Ph.D.

Summary of the Results of Pot Experiments on the Effect of Aldehydes in Different Soils.

With experiments in pots salicylic aldehyde and vanillin had no, or only a slight, harmful action on the growth of plants in Hagerstown loam from Pennsylvania, Chester loam from Virginia, Chester loam from Maryland, Holston fine sandy loam from West Virginia, and Collington fine sandy loam from New Jersey.

The two aldehydes were harmful to plants grown in pots in Susquehanna clay loam from Maryland, sand from Florida, Cecil clay loam from North Carolina, Orangeburg sandy loam from Georgia, Cecil sandy loam from Georgia, Volusia loam from Ohio, and Norfolk sand from Alabama. Of these, the harmfulness was less in the Volusia silty loam. Salicylic aldehyde was applied in amounts of 200 pounds, and vanillin 400 pounds per acre.

When these soils were limed the harmfulness of the aldehyde was overcome altogether. Phosphate fertilizers ameliorated the harmfulness of salicylic aldehyde, and in some cases its effect was entirely overcome. Sodium nitrate lessened the action of vanillin. In soils fertilized with manganese the physiological action of both vanillin and salicylic aldehyde was changed.

The work with the twelve soils in pots further shows that aldehydes do not behave the same in all soils; in five of the soils it had no harmful effects, and in the other seven it was detrimental to growth. The five soils on which it had no harmful action—namely, the two Chester soils, the Holston fine sandy loam, the Hagerstown loam, and the Collington fine sandy loam—were productive field soils, which are in a high state of cultivation, have been manured well, and the general handling and crop manage-

* Continued from page 480, Vol. 186, October, 1918.

ment and drainage are good. By laboratory examination the soils were found to have good oxidizing power, which itself is an indication of a strong fertile soil. The seven soils on which the aldehydes caused a retardation in growth were not as good field soils as the five mentioned above. Their crop-producing power was less, and their general management and cropping were not so good. As a rule, the oxidizing power of these soils was poorer, which indicates an unhealthy condition.

From the field work, which is given in the next section, in which it is shown that the added aldehydes remained in the poor soils and decreased crop growth, and were changed or destroyed in the good soils, consequently having no serious detrimental effects, it is suggestive that the aldehydes were destroyed in the five good soils and were not in the seven poor soils.

In the soils in which the aldehydes produced a harmful effect on the plants lime and manganese greatly aided in lessening the effect of both vanillin and salicylic aldehyde. Phosphate ameliorated the harmfulness of salicylic aldehyde and nitrate of vanillin. As has been pointed out before, lime, nitrate, and manganese stimulate oxidation in most soils. Their beneficial action is probably due to a stimulation of this and other processes in the soil, which in turn act on the organic material and change or destroy it altogether, producing a better condition for plant growth. Aside from the action of this class of fertilizers in causing conditions in the soil preventing the formation or existence of such compounds, methods of cultivation, drainage, and crop management may have the same influence.

FIELD EXPERIMENTS WITH ALDEHYDES.

The field test of the aldehyde compounds were made in plots in the field. In all soil investigations experiments made under field conditions are considered more conclusive than pot tests or aqueous solution cultures. Field tests are influenced by a great many factors which cannot be controlled, and thus, from a strictly scientific point of view, are not as valuable as controlled tests in the greenhouse and laboratory. Yet experiments under field conditions with organic compounds and fertilizers will show the influence of such substances on soil fertility, and their bearing on practical agriculture can thus be determined.

The two aldehydes, salicylic aldehyde and vanillin, with

which the pot studies were made, were tested in the field under varying conditions. These compounds were tested in the field on several soils, differing in geological origin and chemical and biological characteristics, and under different climatic conditions.

Inasmuch as it has been shown that the aldehydes have different effects in different soils, it was necessary in these field tests to demonstrate as to whether the added aldehydes remained as such in the soil, or whether they were destroyed or changed. It would not be expected that the organic substance, when added to a soil in which it was changed or destroyed by oxidation, bacteria, or other biological agencies, would have an effect on the crop grown thereon.

The field experiments were made on the Susquehanna silty clay loam at the United States Experimental Farm at Arlington, Va., in 1913, 1914, and 1915; on the Hagerstown loam at the Pennsylvania Experiment Station at State College, Pa., in 1914 and 1915, and on the Dunkirk clay loam at the Cornell Experimental Station at Ithaca, N. Y., in 1916.

At the Arlington Farm in 1912 three crops were grown: cowpeas, garden peas, and string beans. In this year's experiment the vanillin and salicylic aldehyde were used in plots without fertilizers or lime. In the experiments in the following years at each of the locations cowpeas only were grown. The effect of the aldehydes, when used on soil fertilized with acid phosphate and sodium nitrate, and on limed soil, was determined on each of the soils. Fertilizers and lime influence the biological activities of the soil, and this, in turn, should have an effect on the organic constituents of the soil. A chemical study was made in each of the experiments to determine whether or not the added aldehydes remained as such in the soil during the growing period, or whether they were destroyed or changed.

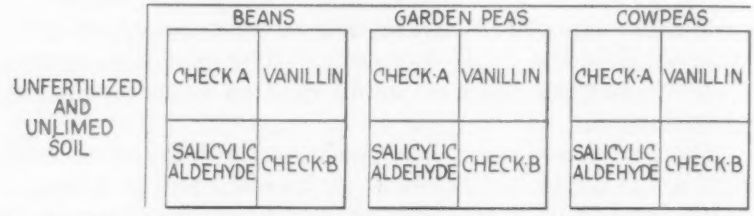
Effect of Salicylic Aldehyde and Vanillin on Cowpeas, String Beans, and Garden Peas on Susquehanna Silty Clay Loam in 1913.

The effect of salicylic aldehyde and vanillin in soils under field conditions was tested on plots at the experiment farm of the Agricultural Department at Arlington, Va., and reported in 1914 and 1915 (58, 68). Three crops were grown; namely, cowpeas, string beans, and garden peas. The treated plot was adjoined on

each side by an untreated plot growing the same crop. Each plot was 8¼ feet square, or one-fourth of a square rod; that is, one six-hundred-and-fortieth of an acre. The plan of the experiment is shown in Fig. 47.

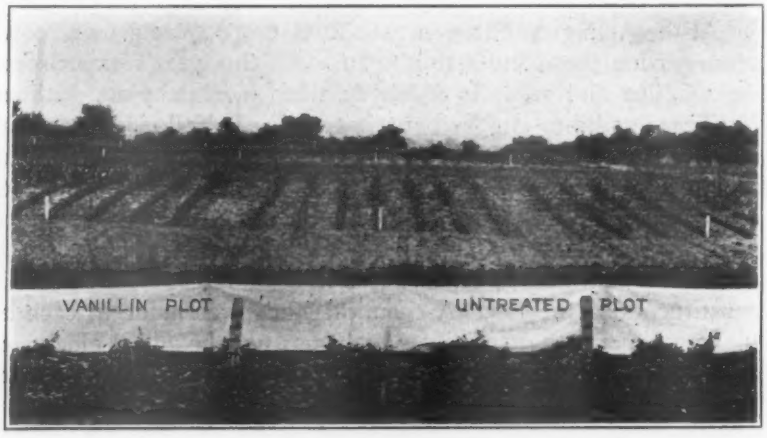
The soil on which these experiments were made is a heavy silty clay loam, low in organic matter. The ground is level and

FIG. 47.



Plan of the aldehyde experiment, growing three crops, on the Susquehanna silty clay loam on the U. S. Experimental Farm at Arlington Va.

FIG. 48.



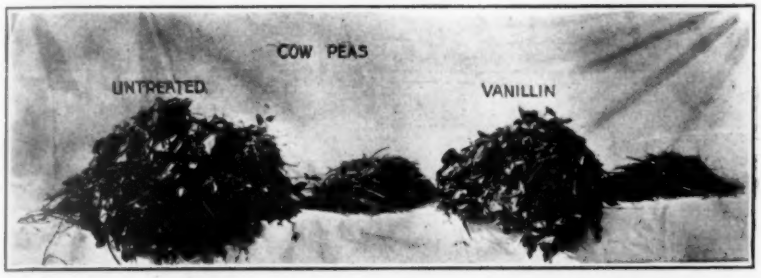
Effect of vanillin on cowpeas on Susquehanna silty clay loam (1913).

has surface drainage. The soil throughout these plots is uniform, and the results secured should not be considered as unduly influenced by irregularities due to non-uniformity of the soil in different plots. The soil is of an acid nature. The land was ploughed early in May and prepared for seeding to the above-named leguminous crops.

The salicylic aldehyde was applied at the rate of 105 pounds

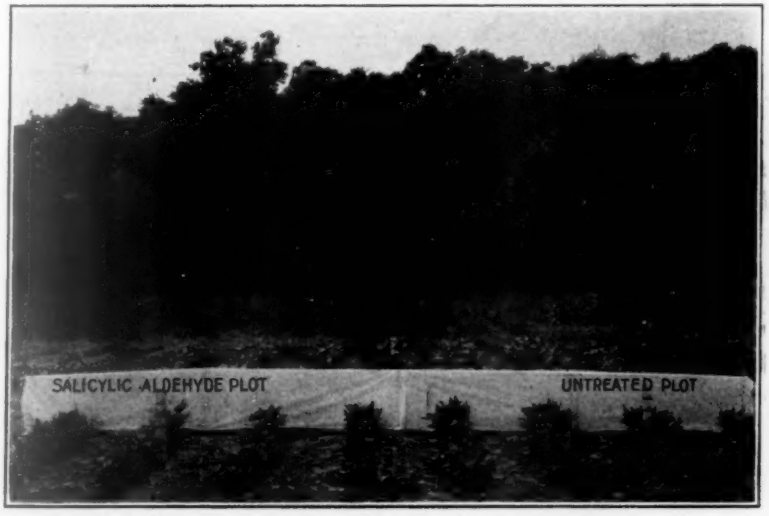
per acre, and the vanillin 285 pounds per acre. The salicylic aldehyde was applied in three portions. One-third of the total amount was applied May 20, one day before the seeds were planted; the second application was made after the plants were

FIG. 49.



Yield of cowpeas, vines and pods on untreated plot and vanillin-treated plot on Susquehanna silty clay loam in 1913.

FIG. 50.



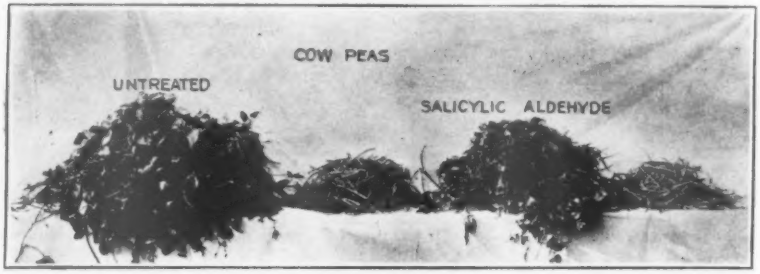
Effect of salicylic aldehyde on cowpeas in the field on Susquehanna silty clay loam in 1913.

up on June 5, and the third on June 24. The vanillin was applied in four portions: May 20, May 28, June 5, and June 24. The material was applied by dissolving in water and pouring in a furrow near the rows of plants.

The crops germinated uniformly. The effects of the aldehyde and vanillin were noticeable from the beginning. The growth was stunted and the plants grew slowly.

Cowpeas.—The cowpeas were planted May 27, 1913, and the crop was harvested September 7. The salicylic aldehyde and vanillin plots produced much smaller plants than the untreated

FIG. 51.



Yield of cowpeas on check plot and on salicylic aldehyde treated plot on Susquehanna silty clay loam (1913).

FIG. 52.

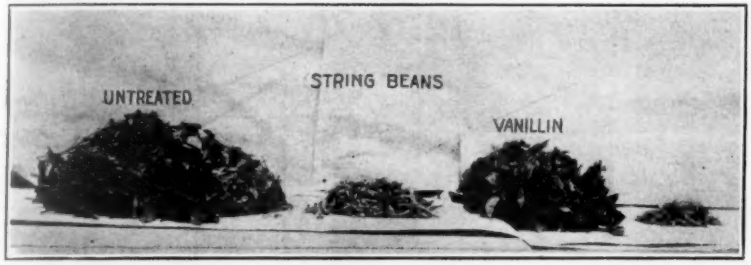
Effect of vanillin on string beans on Susquehanna silty clay loam (1913).

soil. The vanillin-treated plants had a pale-green color and grew slenderer than their untreated checks. The appearance of the vanillin plants while growing is shown in Fig. 48, and of the harvested crop in Fig. 49. The salicylic aldehyde plants are shown in Fig. 50, and the harvested crop in Fig. 51. In these pictures it is seen that the aldehydes have reduced growth

markedly, and it is evident that both compounds have interfered with the development of the plant. The effect became more marked as the plants approached maturity. The yields of green and cured hay and pods per plot and per acre (calculated) are given in Table XIII.

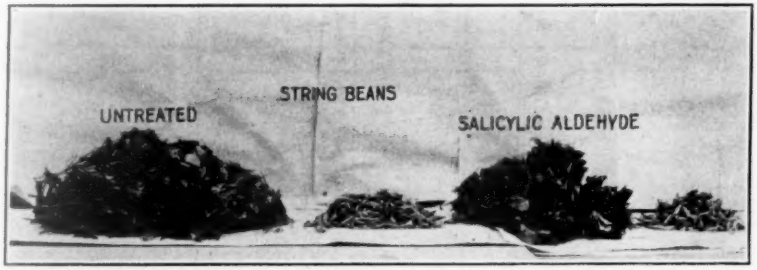
From the table it will be seen that the average yield of green vines plus pods on the check plots was 10.11 tons per acre, and on the salicylic aldehyde plot it was only 6.24 tons per acre, making

FIG. 53.



Yield of string beans, vines and pods, on untreated plot and vanillin plot on Susquehanna silty clay loam in 1913.

FIG. 54.



Yield of string beans, vines and pods, on check plot and salicylic aldehyde treated plot in 1913.

a total decrease of crop 3.87 tons, or 38 per cent. There was a reduction of 50 per cent. in cured hay.

The vanillin plots produced 6.71 tons per acre of green vines plus pods, against 10.11 tons for the check; this is a reduction of 34 per cent. There was a reduction of 39 per cent. in cured hay.

String Beans.—The string beans did not appear to be as much affected in the early stage of their growth by salicylic aldehyde as did the cowpeas or garden peas. This was true even through the

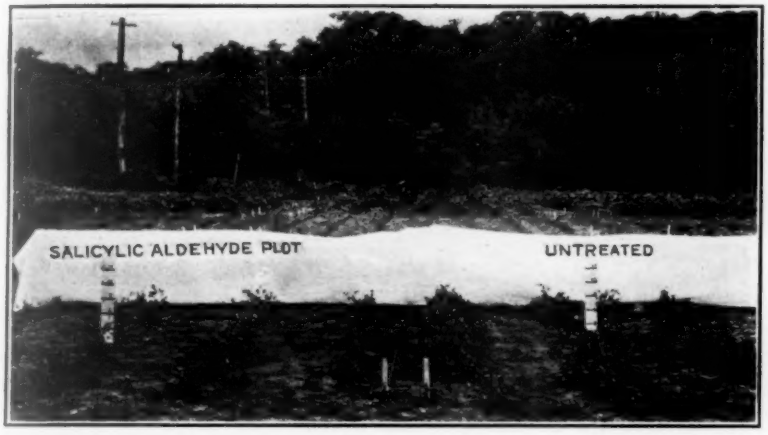
TABLE XIII.

Effect of Salicylic Aldehyde and Vanillin on Cowpeas, String Beans and Garden Peas in Susquehanna Silty Clay Loam in 1913.

	Cowpeas						String beans						Garden peas					
	Yield per plot			Yield per acre			Yield per plot			Yield per acre			Yield per plot			Yield per acre		
	Vines		Pods	Vines		Pods	Vines	Beans		Vines	Beans		Vines	Peas		Vines	Peas	
	Green	Cured		Green	Cured													
	Pounds	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*	*Pounds*	*Pounds*	*Pecks*	*Pounds*	*Pounds*	*Pecks*	*Pounds*	*Pounds*	*Pecks*	*Pounds*	*Pounds*	*Pecks*
Check A	28.00	10.0	6.6	8.96	3.20	2.11	3.55	1.90	4.75	2,272	1,236	190	1.72	1.66	4.50	1,101	1,062	180
Check B	23.00	8.5	5.6	7.36	2.72	1.79	2.94	1.66	4.15	1,882	1,062	166	1.50	1.48	4.00	950	947	160
Average check	25.5	9.3	6.1	8.16	2.96	1.95	3.24	1.78	4.45	2,072	1,149	178	1.61	1.57	4.25	1,030	1,004	170
Salicylic aldehyde	16.0	4.3	3.5	5.12	1.38	1.12	2.71	1.25	3.12	1,734	800	125	.52	.16	.43	333	103	17
Vanillin aldehyde	17.0	5.7	4.0	5.44	1.82	1.27	2.71	.55	1.50	1,734	352	56	1.12	1.14	3.00	717	730	120

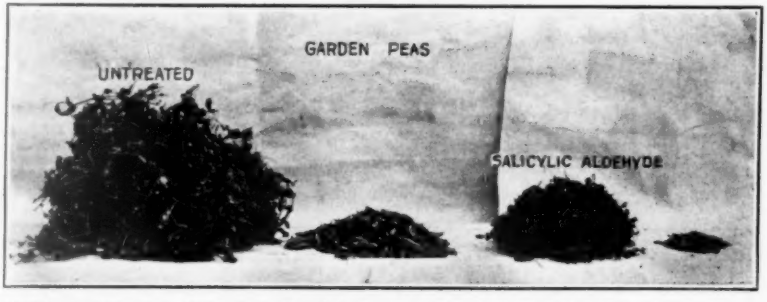
whole period of growth. The vanillin, however, affected them rather severely. As with the other crops, the growth was stunted. The beans were planted May 21, 1913, and were harvested on July 22. The effect of the vanillin on the growing crop is shown in Fig. 52, and the harvested crop is shown in Fig. 53. The

FIG. 55.



Effect of salicylic aldehyde on garden peas in Susquehanna silty clay loam in 1913.

FIG. 56.



Yield of garden pea vines and pods on check plot and on salicylic aldehyde treated plot on Susquehanna silty clay loam (1913).

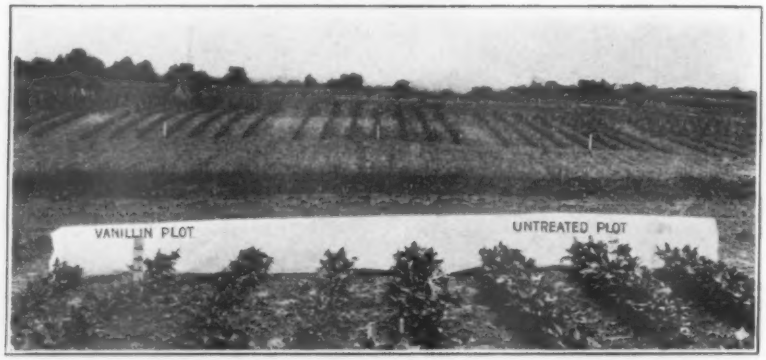
harvested crop from the salicylic aldehyde plot is shown in Fig. 54. The yields are given in Table XIII.

The average yield of vines plus beans per acre of the two check plots was 3219 pounds, against 2534 pounds per acre for the salicylic aldehyde plot, a decrease of 685 pounds of green matter per acre. The yield of marketable beans was reduced 53 pecks per acre.

The yield of vines plus beans from the vanillin plot was 2080 pounds per acre, a reduction of 34 per cent. There was a reduction of 122 pecks of beans per acre.

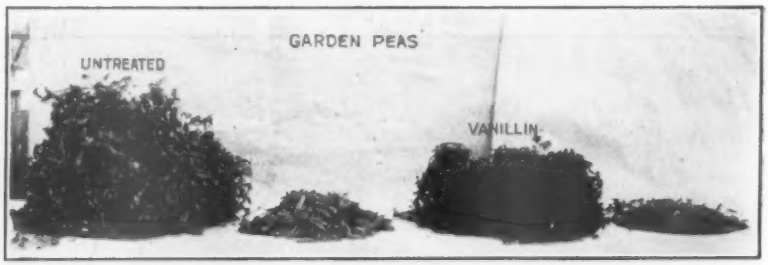
Garden Peas.—The garden peas had made their full growth by June 30, and they were cut on that date. Fruit formation was practically nothing on the salicylic aldehyde plot. The appear-

FIG. 57.



Effect of vanillin on garden peas on Susquehanna silty clay loam (1913).

FIG. 58.



Yields of garden pea vines and pods on untreated plot and vanillin treated plot on Susquehanna silty clay loam in 1913.

ance of the untreated and treated plot on June 24 is shown in Fig. 55. The harvested crops are shown in Fig. 56.

The vanillin checked the growth of the peas from the very start, as it did the cowpeas and beans. The appearance of the growing plants is shown in Fig. 57, and of the harvested crop in Fig. 58. The yields are given in the Table XIII, along with those of the cowpeas and string beans.

The yield of total plant material, vines and pods, was 2034

pounds per acre as an average of the untreated checks, as compared with 435 pounds on the salicyclic aldehyde plot, a decrease of 1599 pounds. The marketable crop—that is, the peas in shell—was depressed from 1004 pounds per acre to 102 pounds, or 90 per cent.—practically a total failure.

As seen from the table, the yield of the vanillin plot is far below the checks. There was a reduction of 30 per cent. in vines and 20 per cent. in marketable peas, due to the presence of vanillin.

Presence of Aldehydes and Their Effect in the Soil Six Months After Application.

The question of the length of time the salicylic aldehyde and vanillin would persist in the Arlington soil and have an influence on its crop-producing power has also been investigated by a chemical study in the laboratory and by plant physiological tests. Samples of soil for these purposes were obtained from the plots the last of November, six months after the substance was applied, and after a crop had been matured. The soils were examined for salicylic aldehyde and vanillin by the method previously described in this paper (61). The three treated plots in each case were found to still contain the added vanillin or salicylic aldehyde.

The existence of the harmful compounds in the soil was also shown in another way by growing wheat in the greenhouse in the soil in paraffined wire pots, using the respective soils from the salicylic aldehyde-treated plots and from the vanillin-treated plots and the check plots. Two pots, with six plants each, were used of each soil. The plants grew from December 11, 1913, to January 6, 1914. The results are given in Table XIV.

TABLE XIV.

Growth of Wheat in Soil Taken from the Field Plots Six Months After Treatment With Salicylic Aldehyde and Vanillin.

Crop grown previously in the field	Growth of wheat plants on			Relative growth check = 100	
	Soil from check plot	Soil from salicylic aldehyde plot	Soil from vanillin plot	Soil from salicylic aldehyde pots	Soil from vanillin pots
	Grammes	*Grammes*	*Grammes*		
Cowpeas	1.48	1.18	1.09	80	74
String beans	1.54	1.11	1.10	72	71
Garden peas	1.47	1.22	1.10	83	75

A similar experiment was made with these soils, except that the crops grown in the pots were identical with those which had grown in the field the preceding season; that is, cowpeas were grown on the cowpea soil from the check plot and from the salicylic aldehyde and vanillin plots, string beans on the string-bean soil from both the check and treated plots, and garden peas on the garden pea soil from the check and treated plots. Two pots were used in each case, and two plants were grown in each pot. The vegetative growth made in this experiment is given in Table XV.

TABLE XV.

Growth of Cowpeas in Soil from the Cowpea Field Plots, String Beans in Soil from the String Bean Field Plots, and Garden Peas in Soil from the Garden Pea Field Plots, Collected Six Months After Treatment With Salicylic Aldehyde and Vanillin.

Crop grown previously in the field	Green weight of plants upon			Relative growth	Check 100
	Soil from untreated plot	Soil from salicylic aldehyde plots	Soil from vanillin plots	Salicylic aldehyde pots	Vanillin pots
	Grammes	*Grammes*	*Grammes*		
Cowpeas	4.30	3.80	3.05	88	71
String beans	7.80	7.20	7.35	92	94
Garden peas	5.60	4.30	4.00	77	71

The tables show that the salicylic aldehyde and vanillin treated soils were still harmful to the respective crops in samples collected six months after the application of the aldehydes and after it had produced the same crop in the field.

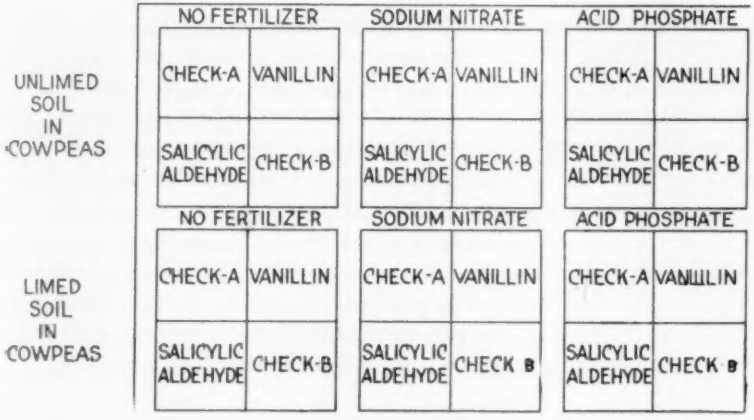
The data here presented show that the salicylic aldehyde and vanillin persisted in the soil on which this experiment was made, at least throughout the growing season. This is demonstrated, first, by the lessened yield of the crop, for if the added material had been destroyed in the soil the plants would not have been injured; second, by the demonstration of its presence at the end of the growing season by means of chemical methods; and third, by the lessened growth of crops in pots containing the treated field soil, six months after the application of the aldehydes in the field.

The next step in this investigation leads us into a study of the action of aldehyde in field soils of different characteristics, the persistence or destruction of aldehyde in different soils, the means by which the substance is destroyed in soils, and the action of fertilizers on the physiological effect of the compounds in soils.

The Action of Fertilizers on Aldehydes in Susquehanna Silty Clay Loam.

The experiments here reported were made on the Arlington Farm in 1914 and 1915. Unlike the experiments just recorded, only one crop, cowpeas, was grown, but the soil treatments were enlarged upon so as to determine the effect of soil aldehydes in soil to which lime and certain fertilizers had been added. Slightly larger amounts of both vanillin and salicyclic aldehyde were used in this test than in the test with the three crops in 1913. At that

FIG. 59.



Plan of the aldehyde—fertilizer experiment on the Susquehanna silty clay loam on the U. S. Experimental Farm at Arlington, Va., and on the Hagerstown loam at the Pennsylvania Experiment Station.

time vanillin was used at the rate of 285 pounds per acre and salicyclic aldehyde at the rate of 105 pounds per acre. In 1914 and 1915 vanillin was used at the rate of 300 pounds per acre and salicyclic aldehyde at the rate of 150 pounds per acre. A similar experiment was made in 1914 and 1915 on the Hagerstown loam at the Pennsylvania Experiment Station. The plan of the experiment used on both soils is shown in Fig. 59.

Both vanillin and salicyclic aldehyde are added to the soil, (1) without fertilizers, (2) with sodium nitrate, (3) with acid phosphate. The aldehydes are also applied to limed soil, with no fertilizers, with sodium nitrate, and with acid phosphate. An examination of the plan of the experiment will show the arrange-

ment of the checks. It is seen that there are two unfertilized checks to compare with the vanillin and salicyclic aldehyde plots. There are two check plots treated with sodium nitrate to compare with the plots which received vanillin or salicylic aldehyde in addition to sodium nitrate; and there are two check plots which received phosphate to compare with the plots which received vanillin or salicylic aldehyde in addition to the acid phosphate. These treatments are repeated on an adjoining strip of ground which had been previously limed at the rate of two tons per acre.

In the Arlington experiment each of these blocks of four plots as shown in the diagram is one square rod, making each plot one six-hundred-and-fortieth of an acre.

Sodium nitrate was added in amounts of 180 pounds per acre and acid phosphate at the rate of 360 pounds per acre. The method of applying these substances was to apply one-third of the total amount before planting, one-third when the plants were about four inches high, and the remaining one-third about four weeks after the second application. The vanillin and salicylic aldehyde were dissolved in water and thoroughly worked into the soil. The fertilizers were applied at the same time and were broadcasted over the plot and raked in. The total amount of lime on the limed plots was applied two weeks before the experiment was started. This was used at the rate of two tons per acre. It was spaded in and well mixed with the soil to a depth of eight inches.

The Susquehanna silty clay loam on which this experiment was made is naturally unproductive. It can be made to produce fair crops by manuring heavily with green manures or stable manure, and it responds to fertilizers well when limed. It is acid, and when the surface soil is neutralized it becomes acid again within a few months, whether growing crops or fallowing.

The Results Obtained in 1914.

Four rows of cowpeas were planted on each plot, May 20, 1914. The Early Buff peas were used, which is an early maturing variety. The seeds germinated well and came up uniformly. In the early stages of growth the plots showed slight differences, and notes taken July 16 are here given.

Unfertilized Section.—The two check plots have made a

growth of about 22 inches in height. The plants have a good dark-green color; they are beginning to put out runners. No blooms are appearing.

The plants on the vanillin-treated plots are stunted in growth. They are one-half to one-third the size of the check-plot plants; average height about 12 inches. There are no runners and no blooms. The vines have a pale-yellow color and do not appear as hardy and thrifty as the check-plot plants. The leaves are distorted, are curled unnaturally, and the ribs are more prominent.

The salicylic aldehyde plot has produced plants of about the size of, or slightly smaller than the vanillin plot. The average height is about 10 inches. They have a lighter green color than check-plot plants, but are not as pale green as the vanillin-plot plants.

Sodium Nitrate Section.—The sodium nitrate check-plot plants are about the size of the plants in the check plots of the unfertilized section. They have a height of 20 to 22 inches. The color is good dark green. A few runners and a few blooms are cut.

The vanillin-plot plants are almost as good as the sodium-nitrate-check plants; they are a little smaller. The color is good, and there is no sign of distorted or disfigured leaves. The average height is 18 to 20 inches. A few runners are starting.

The salicylic-aldehyde-plot plants are smaller than the check plants, about the size of the salicylic aldehyde plants in the no-fertilizer section.

Acid Phosphate Section.—The plants in the acid phosphate check plots are the best of the series. Their height is 28 to 30 inches. The color of the vines is a dark green, and they are healthy and thrifty. The plants are full of runners and have some blooms.

The vanillin-plot plants are much smaller than the checks. The difference between the check plot and the vanillin plot of the acid phosphate section is about as great as the difference between the check plot and the vanillin plot of the no-fertilizer section. There are no runners and no blooms. All the plots of the acid phosphate section are better than the no-fertilizer section.

The growth in the salicylic aldehyde plot is almost as good as in the check plots. The plants have a good color, are thrifty and healthy. There are a few runners.

Limed Soil, No-fertilizer Section.—The plants have made an

excellent growth, they are tall and bushy, and are full of runners and blooms. They are twice the size of the unlimed checks. The color of the foliage is a deep-green color.

The vanillin-plot plants are about the size of the checks; they are full of runners and blooms. There is no indication of a harmful effect.

The growth on the salicylic aldehyde plot is not quite so good as the check. The color is good.

Limed Soil, Sodium Nitrate Section.—The check-plot plants are a little better than the limed unfertilized checks, and growth is bulky and thick.

The vanillin plot is slightly smaller than the check in growth, and the runners are not so numerous. The color is good, and there are no unnatural leaves.

The growth in the salicylic aldehyde plot is about the same as in the check plot. There are lots of runners and blooms.

Limed Soil, Acid Phosphate Section.—The growth on the check plots is better than on the limed no-fertilizer check.

The vanillin-plot plants are slightly smaller than the check; the growth is good and plants healthy.

On the salicylic aldehyde plot the growth is about the same as on the check plots.

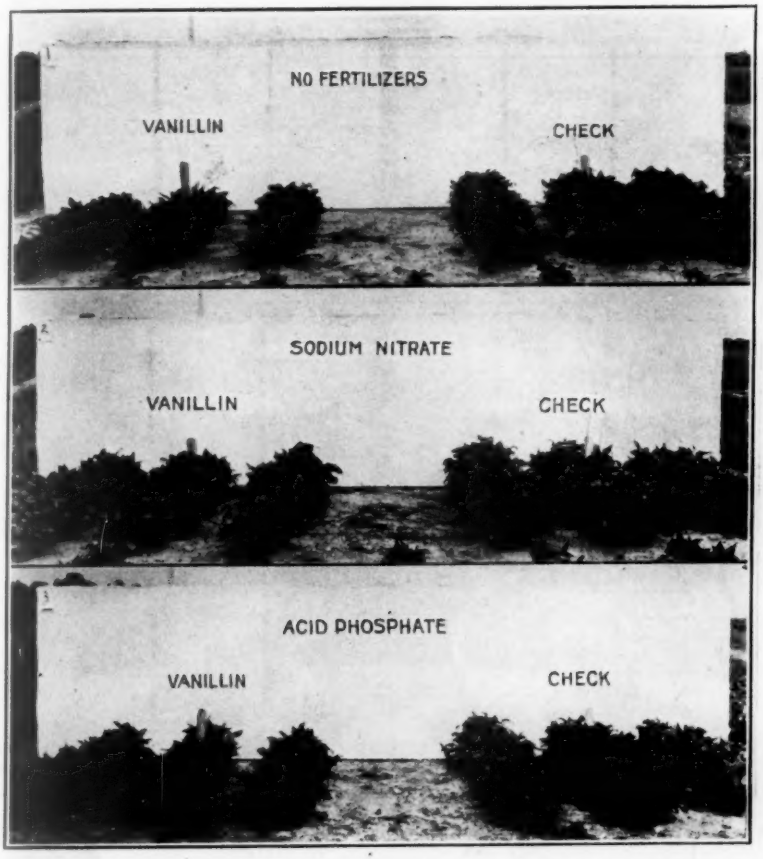
There is very little difference between any of the plots on the limed soil. At this stage of the growth the aldehydes are apparently having no effect in the limed soil.

Photographs were taken July 16 and are reproduced in Figs. 60, 61, 62, and 63. The marked differences in growth on the vanillin and salicylic aldehyde plots are apparent. In Fig. 60 are shown the effect of vanillin on cowpeas in the Susquehanna silty clay loam, the effect of vanillin on the soil fertilized with sodium nitrate, and its effect on the soil fertilized with acid phosphate. As seen in the top cut, the vanillin plants on the left have made a much smaller growth than those on the check plot on the right. In the middle cut the vanillin plot on the left fertilized with sodium nitrate has made almost as good growth as its check plot on the right. The sodium nitrate has overcome to a great extent the effect of the vanillin. In the soil fertilized with acid phosphate the growth, as shown in the bottom cut, is not nearly so good on the vanillin plot on the left as in its check plot on the right. The vanillin has retarded growth as much on the acid

phosphate plots as on the unfertilized soil. The harvested crops are shown in Fig. 61.

In Fig. 62 are shown the effects of salicylic aldehyde on cowpeas grown on unfertilized soil, on soil fertilized with sodium

FIG. 60.

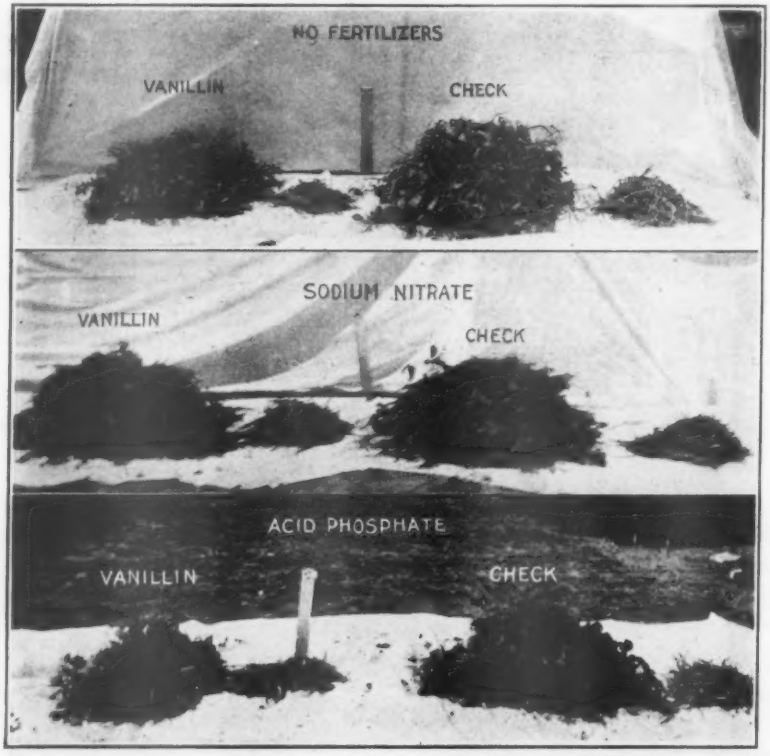


Effect of vanillin on cowpeas in the Susquehanna silty clay loam at Arlington, Va. (1914).

nitrate, and with acid phosphate. In cut 1 the plants on the left, which received the salicylic aldehyde, are much smaller than the check on the right. This is also true with the growth on the soil fertilized with sodium nitrate, cut 2. Here again the salicylic-

aldehyde-treated plants on the left are much smaller than the check plants on the right. The growth on the soil fertilized with acid phosphate is almost as good on the salicylic aldehyde plot as on the check, as shown in cut 3. It seems from this that acid phosphate has an influence in ameliorating the harmful effect of

FIG. 61.



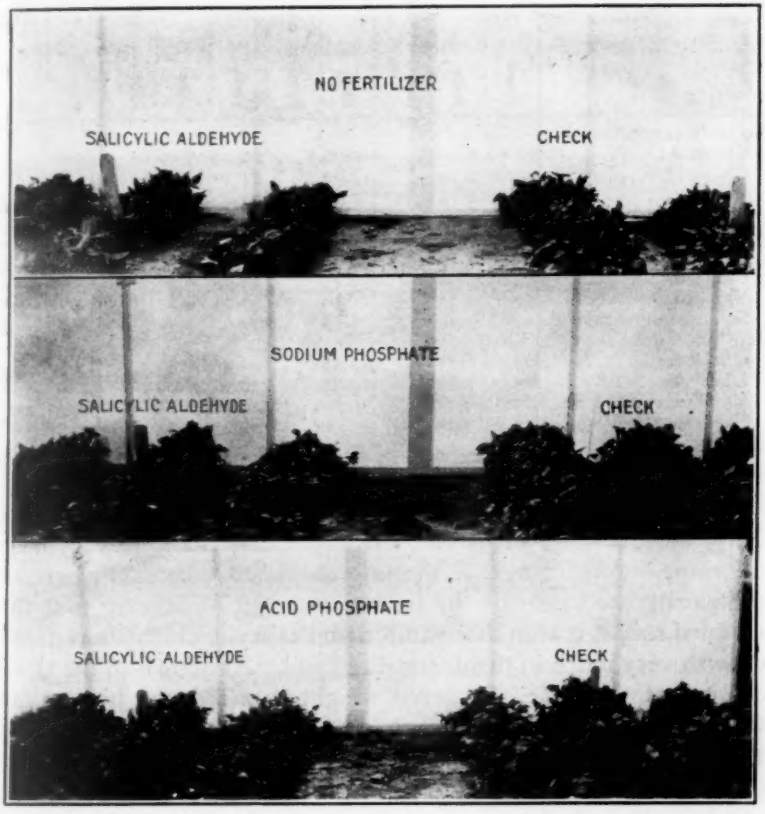
Yield of cowpeas, vines and pods, as affected by vanillin. Grown on the Susquehanna silty clay loam at Arlington, Va. (1914).

salicylic aldehyde in this soil. The harvested crops are shown in Fig. 63.

The cowpeas were harvested August 19. The plants had made their full growth and the seed was ripening. The peas on the lime section were more mature than on the unlimed; the bot-

tom leaves were turning and some were beginning to fall. The vanillin and salicylic aldehyde plots were slower in maturing than their checks. The cowpeas were picked from the vines before they were cut and their weight in pod taken separately. The

FIG. 62.



Effect of salicylic aldehyde on cowpeas in the Susquehanna silty clay loam at Arlington, Va. (1914).

green weight of the vines was taken, and then the vines were spread back upon the plot and allowed to dry. The dry weight of the cured cowpea hay was taken August 24. The results for each plot are given in Table XVI.

TABLE XVI.

Effect of Vanillin and Salicylic Aldehyde on Cowpeas Grown in the Field on Susquehanna Silty Clay Loam in 1914, and the Action of Fertilizers in Modifying Their Effect (Weights Given in Pounds Per Plot).

Treatment	Unlimed soil					Limed soil				
	Green weight			Dry weight		Green weight			Dry weight	
	Vines	Pods	Relative total weight	Hay	Relative weight	Vines	Pods	Relative total weight	Hay	Relative weight
No-fertilizer section:										
Check A	21.50	6.00	100	10.00	100	26.00	9.50	100	15.00	100
Check B	22.00	6.75		11.00		24.50	8.75		13.75	
Vanillin	13.50	4.25	67	7.50	71	23.00	9.75	107	14.25	99
Salicylic aldehyde	10.50	3.75	59	5.75	55	18.50	7.00	77	10.75	71
Sodium nitrate section:										
Check A	24.50	7.25	100	12.50	100	27.50	9.75	100	15.75	100
Check B	23.25	7.50		12.25		25.75	8.50		15.00	
Vanillin	21.00	6.75	91	11.50	91	27.75	9.25	101	14.75	96
Salicylic aldehyde	15.25	4.00	54	8.75	70	22.00	7.50	83	12.50	82
Acid phosphate section:										
Check A	25.50	7.75	100	14.25	100	29.25	9.50	100	15.50	100
Check B	25.00	7.25		13.75		32.00	10.00		16.25	
Vanillin	19.00	6.00	80	10.00	71	29.00	8.75	90	14.75	93
Salicylic aldehyde	23.75	7.25	97	13.00	93	29.75	9.25	95	15.50	98

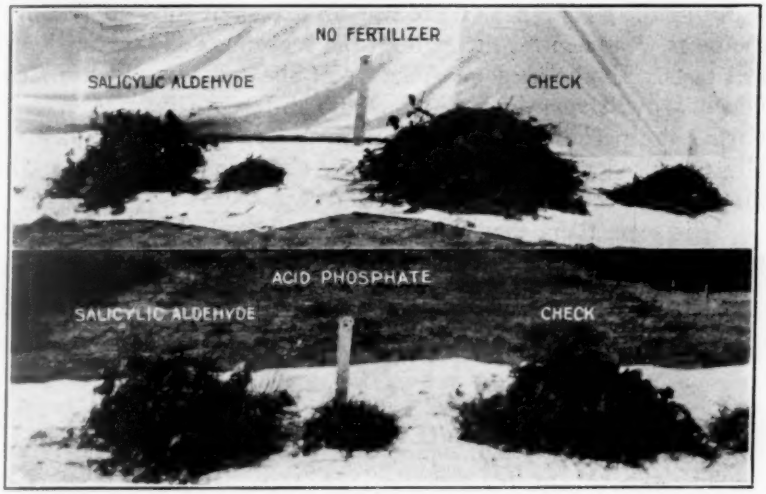
An examination of the table shows that the check plots were fairly uniform; the yields on these duplicate plots were very near the same. An average of the two checks will be taken here in comparing the yields of the treated plots. Considering first the unlimed soil, it is seen that vanillin and salicylic aldehyde reduced growth very much in the unfertilized soil. As shown in the third column of the table, the green weight was reduced by vanillin from 100 to 67, or 33 per cent., and by salicylic aldehyde from 100 to 59, or 41 per cent. The weight of cured hay was reduced by vanillin from 100 to 71, a reduction of 29 per cent., and by salicylic aldehyde from 100 to 55, a reduction of 45 per cent.

In the plots fertilized with sodium nitrate the vanillin reduced the growth only 9 per cent. in both green weight and dry weight; that is, from 100 for the check to 91 for the vanillin-treated plot. The salicylic aldehyde reduced growth in green weight from 100 for the check to 54, a 46 per cent. decrease, and in dry weight from 100 for the check to 70, a reduction of 30 per cent.

In the plots fertilized with acid phosphate the vanillin reduced the green weight from 100 for the check to 80, a reduction of 20 per cent., and the dry weight from 100 to 71, a reduction of 29 per cent. The salicylic aldehyde reduced the green weight from 100 for the check to 97, a reduction of only 3 per cent., and in cured hay from 100 to 93, a reduction of 7 per cent.

Both of these compounds, then, had a harmful effect in this soil. The harmfulness of vanillin was partly overcome by sodium nitrate, but was just as harmful with acid phosphate, and the

FIG. 63.



Yield of cowpeas, vines and pods, as affected by salicylic aldehyde. Grown on the Susquehanna silty clay loam at Arlington, Va. (1914).

bad effects of salicylic aldehyde were partly overcome by acid phosphate, but sodium nitrate had no such helpful function.

Considering now the limed soil, given in the last half of the table, it is seen that the vanillin had no harmful effects in the unfertilized soil. The salicylic aldehyde reduced growth in green weight from 100 for the check to 77, or a reduction of 23 per cent., as against 41 per cent. for the unlimed plot. In dry weight there was a reduction of 29 per cent., as against 45 per cent. for the unlimed plot.

In the sodium nitrate plots the growth in the vanillin plot was approximately the same as in the checks. The salicylic aldehyde reduced growth from 100 for the check to 82, a reduction of 18 per cent. in both green and dry weight, and practically the same in dry weight.

In the acid-phosphate-treated soil the vanillin plot reduced growth in green weight from 100 for the check to 90, and in dry weight from 100 to 93. This apparent harmful effect of vanillin in the limed soil with acid phosphate is probably accidental, as in the other plots where lime was used no harmful effects were observed.

With the amount of acid phosphate used increased acidity is out of the question, as there was an excess of lime applied and the plots were neutral throughout the season, as shown by chemical tests. In the acid phosphate plot the salicylic aldehyde reduced growth very little; in fact, no difference was observable during the period of growth, but in green weight the aldehyde plot produced 5 per cent. less than the check, while in dry weight there was a reduction of only 2 per cent.

It is seen, then, that in the limed soil vanillin had practically no harmful effect. The harmfulness of salicylic aldehyde was greatly lessened, and with acid phosphate and lime together practically no harmful effects were observed.

The Results Obtained in 1915.

The experiment just described was repeated on the same plots in 1915, and in every detail is a duplicate of the former experiment. The seeds were planted May 29, and by July 7 the plots were showing considerable differences. Again this year the vanillin and salicylic aldehyde on the unfertilized soil checked growth very much. In the soil fertilized with sodium nitrate the harmfulness of vanillin was overcome to a certain extent, and, as before, the harmfulness of salicylic aldehyde was lessened by acid phosphate fertilization. The limed plots again produced better growth than the unlimed, and the effect of the aldehydes was only slight. The crop was harvested August 27. This year the peas were not picked from the vines; the green and dry weights of the vines and peas together are given in Table XVII.

TABLE XVII.

Effect of Vanillin and Salicylic Aldehyde on Cowpeas Grown in the Field on Susquehanna Silty Clay Loam in 1915, and the Action of Fertilizers in Modifying their Effects (Weights Given in Pounds Per Plot).

Treatment	Unlimed soil				Limed soil			
	Green weight		Dry weight		Green weight		Dry weight	
	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight
No-fertilizer section:								
Check A	32.0	100	14.0	100	46.0	100	21.0	100
Check B	34.0		16.0		44.0		20.0	
Vanillin	26.0	79	11.5	77	47.0	104	21.0	102
Salicylic aldehyde	24.5	74	11.0	73	41.0	91	18.5	90
Sodium nitrate section:								
Check A	42.0	100	21.5	100	46.0	100	20.5	100
Check B	39.5		18.5		44.5		19.0	
Vanillin	39.5	97	18.0	90	44.5	85	18.5	93
Salicylic aldehyde	34.5	85	16.0	80	45.0	100	18.5	93
Acid phosphate section:								
Check A	36.0	100	20.0	100	47.0	100	20.0	100
Check B	33.5		18.5		44.0		17.0	
Vanillin	31.5	91	15.0	80	43.0	94	18.5	100
Salicylic aldehyde	32.5	93	17.0	88	44.5	98	17.0	92

By an examination of the table it is seen that the data, in the main, support the results secured in the former years. That salicylic aldehyde and vanillin are harmful in this soil and that lime overcomes the effect of both compounds, and that sodium nitrate lessens the harmful action of vanillin, and acid phosphate that of salicylic aldehyde, seem well established.

Examination of the Soils for Aldehyde at the End of the Growing Period.

Samples of soil were taken from each plot August 24, 1914, the day on which the crops were harvested, for the purpose of examining them in the laboratory to ascertain if the vanillin and salicylic aldehyde were still present in the soil.

An acidity test made of the various plots showed that each of the unlimed plots was acid and all of the limed plots were neutral or slightly alkaline.

Soil from each plot was examined for aldehydes by the method already described in this paper and in Bulletin 88, Bureau of Soils, and in Bulletins 108 and 164 of the United States De-

partment of Agriculture. In this work with vanillin- and salicylic-aldehyde-treated soils it was merely determined as to whether aldehyde material was still present or not.

Soil from the untreated plots, subjected to the above-described process, was found to contain no aldehydes. The plot to which vanillin had been added, but no fertilizers, was found to contain aldehyde. After making the color reactions the remaining portion of the residue was dissolved in water and used as a culture solution for the growth of wheat seedlings. Seedlings were grown in distilled water without the residue as a check. Growth was reduced by the extracted substance 30 per cent., showing it to be very harmful to wheat plants.

No aldehyde was found in the soil from the plots treated with vanillin and sodium nitrate, or with vanillin and acid phosphate. The ether extract secured in the process of the isolation of aldehyde usually gives a residue of some kind. The residue secured from these two soils, when dissolved in distilled water, showed no harmful effects on wheat plants, so, whatever this residue was, it was not harmful to plants, as was that from the unfertilized plot, which by the color reactions showed it to contain aldehydes.

Soils from the plots to which salicylic aldehyde, salicylic aldehyde and sodium nitrate, and salicylic aldehyde and acid phosphate were added were examined, and each was found to contain aldehyde. In each case there was a good amount of residue from the ether extract, which gave the color reactions for aldehyde. In the plant test the residue from the salicylic aldehyde plot reduced growth 25 per cent.; from the salicylic aldehyde and sodium nitrate plot, 7 per cent.; and from the salicylic aldehyde and phosphate plot, 11 per cent. The material extracted from each of these soils was harmful; there was considerably more effect from the substance from the salicylic aldehyde unfertilized plot than from the other two.

No indications of the presence of aldehydes were found in any of the soils from the limed plots, which would tend to show that the added vanillin and salicylic aldehyde did not remain in the soil as such during the growing season. Lime might either have a direct chemical effect or stimulate oxidation and life-processes in the soil, which would cause such substances as aldehydes to be oxidized or otherwise changed. The vanillin and salicylic aldehyde had very little effect on the crop in the limed plots, which is

in harmony with the fact that they were not found to remain in the soil under these conditions.

It might also be pointed out that the sodium nitrate partly overcame the effects of vanillin, and at the end of the growing season no vanillin was found in the soil, which would indicate that sodium nitrate fertilizer made conditions such that vanillin would not exist in this soil. Neither was vanillin found at the end of the experiment in the soil to which acid phosphate had been added, yet the vanillin had affected the growth, which may have occurred when the material was first added to the soil.

The salicylic aldehyde with and without fertilizers was found to remain in the unlimed soil throughout the growing season; however, the acid phosphate greatly lessened its effects on growth. These methods for the isolation of aldehydes are not quantitative, and it may be that only a small part of the aldehyde remained in the soil, while most of it was changed or destroyed and did not long remain to influence plant growth.

At the end of the crop season in 1915 the soils from each plot were also examined for aldehydes. Of the unlimed plots to which vanillin had been added, aldehydes were found to be present in both the no-fertilizer vanillin plot and in the acid phosphate vanillin plot. The material isolated from both of these soils was harmful to wheat seedlings in distilled water. No aldehyde was found in the vanillin plot which had been fertilized with sodium nitrate.

Each of the unlimed plots to which salicylic aldehyde had been applied was found to contain aldehyde at this time, and this isolated aldehyde material proved to be harmful to wheat plants in each case.

No aldehydes were found in any of the plots on the limed soil, showing the complete disappearance of these substances under the influence of lime.

In both 1914 and in 1915 vanillin and salicylic aldehyde added to the unlimed soil remained as such to affect crop growth throughout the growing season. In both years the aldehydes had only a slight effect on crop growth in the limed soil, and now, when the soil is examined at harvesting time, none is found to have persisted in the soil throughout the season.

In both 1914 and 1915 vanillin added to the soil fertilized with sodium nitrate was not found to be present several months

after its application. It appears that sodium nitrate acts in the soil in such a way as to destroy vanillin or change it to more highly oxidized compounds that are not harmful to plant growth.

The behavior of these compounds as to their effect on crop growth and as to their permanency in another type of soil which is entirely different in character and in a different climate will be interesting to compare with the experiments at Arlington. It has been shown that even on the Arlington soil under different fertilizing practices the substances behave differently. The experiments on the Hagerstown loam in Pennsylvania were conducted to study these effects on a more fertile soil.

Before presenting the results obtained on this more fertile soil, having a higher oxidation capacity, it will be well to present some experiments and observations made as to the influence of this oxidation factor as determined on the differently treated and differently fertilized plots on the Arlington soil. The experiments seem to indicate a certain relationship between increased oxidation on the one hand and decreased toxicity and destruction of aldehydes on the other.

Effect of Vanillin and Salicylic Aldehyde on the Oxidation of the Soil.

Oxidation by plants is a factor which has considerable bearing on soil fertility. By oxidation the plant may change the organic matter in the medium in which it is growing. The oxidizing power of plant roots grown in extracts of productive soils is greater than that of plant roots grown in extracts of unproductive soils. The presence of vanillin and cumarin in a culture solution greatly checked oxidation by the plant roots (45). Soils themselves have oxidizing power, and the degree of oxidative power which a soil possesses varies with the soil. As a rule, soils that are known to be productive have strong oxidative power and poor soils have little or no oxidative power. Whatever decreases oxidation in soils tends also to bring about conditions which decrease growth, and the factors which favor oxidation are the factors which favor soil productivity.

The oxidative power of the silty clay loam at Arlington is relatively poor as compared to other agricultural soils, and the oxidation of the Hagerstown loam at State College, Pa., on which the aldehyde experiments were also made, is very good; in fact,

the oxidation in this soil was found to be among the best of a long list of soils tested (59). Oxidation studies were made of the soils on the Arlington plots to determine the effect of added vanillin and salicylic aldehyde.

For this purpose samples were taken July 16, 1915, before the last application of aldehydes was made; July 23, seven days after the last application, and on November 19, about two and one-half months after the crops were harvested and four months after the last application of aldehydes. The method used in testing the oxidative power of these soils is the same as that described in Bulletin 56 of the Bureau of Soils. The method, in brief, consists of shaking 20 grammes of soil in a water solution of aloin, allowing to settle and adding 50 c.c. of alcohol to flocculate the soil and to extract the oxidized aloin. The solution is then centrifuged, the supernatant liquid poured off, and the depth of color in the solutions compared by means of a colorimeter.

The oxidation of the untreated plot and the effect of sodium nitrate, acid phosphate, and lime on the oxidation of the soil will first be considered. The relative oxidation of the fertilized plots as compared with the untreated soil is given in Table XVIII.

TABLE XVIII.

Effect of Fertilizers and Lime on Soil Oxidation in Susquehanna Silty Clay Loam.

	Relative oxidation			Average oxidation
	July 16	July 23	November 19	
Soil untreated	100	100	100	100
Soil + sodium nitrate	131	127	121	126
Soil + acid phosphate	109	95	99	97
Soil + lime	138	134	100	124
Soil + lime + sodium nitrate	147	144	121	137
Soil + lime + acid phosphate	131	121	81	111

The oxidative power of the samples taken July 16 are given in the second column of the table; in the third column is given the oxidation of the soil July 23, and in the fourth column the oxidation on November 19. In the last column the averages of the three periods are given.

It is seen from the table that sodium nitrate had greatly increased the oxidation of the soil. At each period the oxidation was greater in the sodium nitrate plot than in the untreated plot.

The average for the three periods was 126 for the sodium nitrate, against 100 for the check plot.

The acid phosphate increased oxidation only once, and that was in the first period. At the other two periods the oxidation was less than the untreated soil. An average of the three periods gave an oxidation of 97 for the acid phosphate plot, against 100 for the check.

The limed soil also increased oxidation; in the first two periods the oxidation was greater than the check plot, and in the third period the check and the limed plots were the same. An average of the three periods gave 124 for the limed soil, against 100 for the check.

It is also seen that lime plus sodium nitrate increased oxidation greater than any other treatment. The average for the three periods was 137, against 100 for the check.

Lime plus acid phosphate caused less oxidation than lime alone, yet there was, on the whole, more oxidation than in the untreated soil. The oxidation of the lime and phosphate plot was less in each period than in the limed plot. Inasmuch as phosphate decreased oxidation when used alone and again when used with lime, it appears that acid phosphate hinders the oxidative power of this soil.

In previous work in this laboratory it was shown that fertilizers influenced the oxidation in Arlington soil, sodium nitrate greatly increased oxidation, and phosphate only slightly. With some other soils this was also found to be true; however, in numerous experiments made on the effect of fertilizers on the oxidative power of soils the results showed that fertilizers sometimes increased oxidation and sometimes decreased it, and that the effects of fertilizers are different in different soils (59).

The oxidizing power of plant roots is also influenced by calcium carbonate and fertilizer salts. Calcium carbonate increases the oxidative power of plants growing in distilled water and in soil extracts. Sodium nitrate also has this power. Calcium acid phosphate, however, depressed the oxidizing power of the plants in soil solutions (45). Thus the results secured on the Arlington plots are in accord with those secured in the earlier work on the oxidation of soils and on the oxidizing power of plants in soil solutions.

Interesting results were obtained with the effect of vanillin

and salicylic aldehyde on the oxidizing power of the Arlington soil. The relative oxidation of these plots is given in Table XIX.

TABLE XIX.

Effect of Vanillin and Salicylic Aldehyde on Soil Oxidation in Susquehanna Silty Clay Loam.

Treatment	Unlimed soil				Limed soil			
	July 16	July 23	November 19	Relative average oxidation	July 16	July 23	November 19	Relative average oxidation
Soil unfertilized	100	100	100	100	100	100	100	100
Soil+vanillin	104	96	94	98	81	89	89	98
Soil+salicylic aldehyde	89	85	81	85	95	89	89	93
Soil+sodium nitrate	100	100	100	100	100	100	100	100
Soil+sodium nitrate+vanillin	86	72	93	84	89	100	77	89
Soil+sodium nitrate+salicylic aldehyde	95	82	93	90	100	89	87	92
Soil+acid phosphate	100	100	100	100	100	100	100	100
Soil+acid phosphate+vanillin	82	80	100	87	100	100	80	100
Soil+acid phosphate+salicylic aldehyde	100	109	112	107	105	119	157	127

In this table the soil without vanillin or salicylic aldehyde in each case is taken as 100; that is, the plots unfertilized are compared among themselves, and each group fertilized is similarly compared with its own treated check as 100.

The first half of the table gives the results on the unlimed soil and the second half the results on the limed soil. As in the preceding table, the oxidation for the three periods is given, and an average of the periods.

In the unfertilized soil vanillin reduced the oxidation slightly. In the first period there was a slight increase and in the other two periods a slight decrease. An average of the three periods showed a decrease in oxidation in the vanillin plot to 98, as compared to 100 for the check. The salicylic aldehyde decreased oxidation very much in each period. An average of the three periods gave an oxidation of 85 for the treated plot, against 100 for the check.

In the soil treated with sodium nitrate the oxidation power of the vanillin plot was much less in each period than in the sodium nitrate check. The salicylic aldehyde was also less than the check, but the oxidation was not lessened as much as in the

vanillin-treated soil. It should be remembered, however, that the sodium nitrate check plot had itself increased greatly in oxidation over the untreated soil, which means that the soil in each of those plots has very good oxidation, and much better than in the corresponding plots in the no-fertilizer section. Yet the vanillin and salicylic aldehyde have their influence in checking oxidation even with this fertilization.

Considering the section treated with acid phosphate, vanillin had lessened oxidation, yet the salicylic aldehyde has slightly increased this function over the acid phosphate check.

In the limed soil the compounds have also decreased the oxidizing power of the soil, except plots to which acid phosphate was added. Where lime and phosphate were used together the oxidation in the vanillin plot was the same as in its check, and in the salicylic aldehyde plot the oxidation was increased from 100 for the check to 127. It should also be borne in mind that the limed check plots had a very good oxidizing power, which was greater than in the unlimed, unfertilized soil, which means that each of the plots on the limed soil had a greater oxidizing power than the corresponding plot on the unlimed soil. However, the oxidizing power of the soil was decreased by applying vanillin and salicylic aldehyde, except where acid phosphate was used. This action of acid phosphate in combating the effects of salicylic aldehyde, and of vanillin to some extent, is rather surprising. In the former work, and also in the plots in this experiment, where no aldehydes were used, the acid phosphate did not have an appreciable influence in stimulating oxidation processes in the soil. However, this increased oxidation is in harmony with the increased crop yields and with the effect of phosphate in lessening the harmfulness of salicylic aldehyde to plant growth.

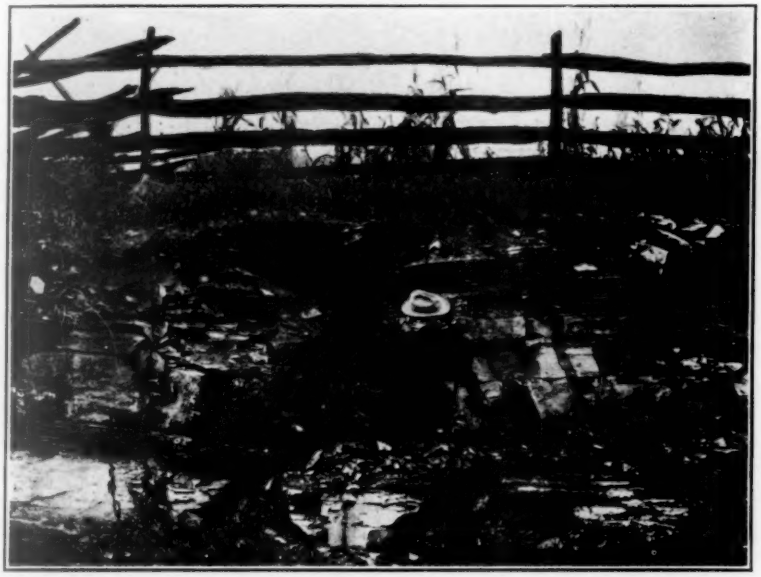
The Effect of Aldehydes With and Without Fertilizers on Hagerstown Loam.

The test of the two aldehydes was made on the Hagerstown loam (32) on the Pennsylvania Experiment Station Farm at State College, Pa., in 1914 and 1915. The plan of the experiment is given in Fig. 59, and is the same as was used at Arlington. The size of the plots differed, however. The plots at State College were 10 feet square, one four-hundred-and-thirty-fifth of an

acre. Early Buff variety of cowpeas, the same as used at Arlington, was grown.

The field in which the experiment was made is in a good state of fertility. In 1913 the field grew corn and produced a good crop. It was manured with stable manure at the rate of 12 tons per acre. The soil produces good crops of wheat, grass, clover, corn, and soy beans.

FIG. 64.



Limestone rock from which the Hagerstown soils are derived: showing the formation of the Hagerstown loam soil of Pennsylvania from limestone rock—a soil in which aldehydes do not persist.

The surface soil of the experiment plots consists of about 10 inches of brown to yellowish-brown loam. It is underlaid from 10 to 20 inches by a yellowish-brown, heavy silty loam which grades to a heavy red clay within three feet. The soil is loose and friable, and is very easily worked. The drainage is excellent. The Hagerstown loam of this area is formed from disintegrated dolomite, and is recognized as among the best soils of the country and by far the most productive soil of Center County (Fig. 64).

The soil in the experiment plots contains considerable organic matter, fully as much as the soils of this type in this area. A

laboratory test showed the soil to be only slightly acid. The ground selected for the plots is 72 feet by 44 feet, the plan of which is given in Fig. 59. Each plot is separated by a two-foot path. There is a very slight but uniform slope from the north plots; that is, the no-fertilizer group of plots. The soil of this piece of ground is fairly uniform. The vanillin plot and check B plot of the acid phosphate section on the limed soil are the lowest plots of the entire series; the slope is toward them, and they are somewhat darker and richer in organic matter.

The Results Obtained.

The general details of the experiment as to the application of the aldehydes, fertilizers, etc., are the same as those described in the Arlington test. In 1914, the first year's test, the cowpeas were planted May 27, five rows to each plot; unfortunately the season was very dry during May and June, and as a result of this a very poor stand was secured. The experiment was unsatisfactory in that a uniform stand was lacking, and it was unsafe to draw any conclusion from the results. However, there were very little differences in the growth on the differently treated plots. The weights of the vanillin plot show a reduction of six per cent. in dry weight of hay. The yield of cured hay on the salicylic aldehyde plot was practically the same as on the check plots. The indications show that the vanillin and salicylic aldehyde have very little effect on this soil.

The experiment was conducted the second year, 1915, on the identical plots used in the first test, and the results secured are more satisfactory and conclusive. The peas germinated well and a uniform stand was secured. When the plants were two to three inches high the growth on the vanillin and salicylic aldehyde plots of the unfertilized section appeared to be slightly behind the plants on the other plots.

On July 19 the plots were showing some differences in growth. On the unlimed soil the two checks in the no-fertilizer section had made about equal growth. The plants on the vanillin plot had made less growth than the checks. They appear about 20 per cent. smaller. They are not as tall nor have they broadened out as much as the checks.

On the salicylic aldehyde plot the growth is much better than

the vanillin plot, but it is not as good as the check plots. There seems to be a difference of about 10 per cent. in growth.

On the fertilized soil the growth on the differently treated plots is more uniform; the plants on the vanillin and salicylic aldehyde plots are somewhat smaller than the checks. The

FIG. 65.

Effect of vanillin on cowpeas on Hagerstown loam at the Pennsylvania Experiment Station (1915).

growth, on the whole, is good on all the plots; the plants are strong, healthy, and thrifty.

On September 9 photographs were taken of some of the plots, and these are shown in Fig. 65. At this time the vanillin and salicylic aldehyde plots of the no-fertilizer section on the unlimed soil were smaller than their checks. This was especially true of the vanillin plot. On the sodium nitrate section the growth on

the vanillin plot was almost as good as the respective check.

The crop was cut and weighed September 13. The plants had made their full growth, but were still green and full of blooms. The weight of the entire plant was taken; no attempt was made to pick the peas, as they were immature.

After the green weight was taken the vines were spread upon the plots and allowed to become dry. The weight of the cured hay was taken September 15, and the yields are given, together with the green weights, in Table XX.

As seen in the table, the two check plots in the no-fertilizer section of the unlimed soil produced approximately the same yield. The vanillin reduced the green weight yield from 100 as an average of the two checks to 84, a reduction of 16 per cent. In dry weight there was also a 16 per cent. decrease. The salicylic aldehyde reduced growth in green weight from 100 to 88, a reduction of 12 per cent., and in dry weight from 100 to 87, or 13 per cent.

On the sodium nitrate soil the aldehyde had less harmful effects. The vanillin reduced the yield only three per cent. in green weight, and in dry weight there was an increase of two per cent. As the crop grew it was apparent that the growth on the vanillin plot was as good as the checks. The foliage and the number of runners were about the same on both plots. This action of nitrate in overcoming the harmfulness of vanillin is in harmony with the result secured in the Arlington soil. The growth on the salicylic aldehyde plot was not altogether as good as the checks. The foliage was not so dense and there were fewer runners. In the table it is seen the green weight was reduced from 100 to 90, a reduction of 10 per cent., and in dry weight there was a reduction of 9 per cent.

In the acid phosphate section the growth on the vanillin plot was somewhat smaller than on the checks; considering the green weight, growth was reduced from 100 to 91, a reduction of 9 per cent., and in dry weight a reduction of 13 per cent. On the salicylic aldehyde plot the growth was as good as on the checks. This was apparent before the crop was cut. The density of the foliage and the number of runners was about the same on both plots. The behavior of phosphate in ameliorating the effects of salicylic aldehyde is also in harmony with the Arlington results.

On the unfertilized section of the limed soil neither vanillin

nor salicylic aldehyde had very much effect. In green weight there was a reduction of 9 per cent. in the vanillin plot and 8 per cent. in the salicylic aldehyde plot. The reduction in dry weight was 15 per cent. for vanillin and 7 per cent. for salicylic aldehyde.

TABLE XX.

Effect of Vanillin and Salicylic Aldehyde on the Growth of Cowpeas on Hagerstown Loam at State College, Pa., and the Effect of Fertilizers and Lime. (Results Given in Pounds Per Plot.)

Treatment	Unlimed soil				Limed soil			
	Green weight		Dry weight		Green weight		Dry weight	
	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight
No-fertilizer section:								
Check A	59.00	100	21.75	100	62.50	100	23.50	100
Check B	60.25		22.50		61.00		23.50	
Vanillin	50.00	84	18.50	84	56.00	91	20.00	85
Salicylic aldehyde	53.50	88	19.25	87	57.00	92	21.75	93
Sodium nitrate section:								
Check A	63.00	100	23.25	100	58.00	100	21.00	100
Check B	60.00		22.75		55.50		21.25	
Vanillin	59.50	97	23.50	102	55.00	97	21.50	102
Salicylic aldehyde	55.50	90	21.00	91	55.00	97	22.50	106
Acid phosphate section:								
Check A	59.00	100	22.00	100	62.00	100	24.25	100
Check B	61.00		24.50		67.00		28.25	
Vanillin	54.50	91	20.25	87	67.00	104	*26.75	102
Salicylic aldehyde	61.50	103	23.25	100	61.00	95	*23.25	89

* See discussion in the text.

On the limed soil fertilized with sodium nitrate or acid phosphate neither aldehyde had any appreciable harmful effect.

A close examination of the table shows that the yields of the duplicate check plots are very close together, except in the acid phosphate section of the limed soil. Check A produced only 62 pounds green matter and 24¼ pounds dry hay, while Check B produced 67 pounds green matter and 28¼ pounds dry hay. This difference was apparent during the growing season. On close examination of the soil of the two plots it was found that the surface soil in Check B was several inches deeper and had more organic matter. This was also true of the adjoining vanillin plot. The lay of the ground is such as to make it possible for Check B plot and the vanillin plot to get the drainage from several of the surrounding plots. Under the circumstances, in this section it would be better to compare the vanillin plot with Check B, and

the salicylic aldehyde plot with Check A. By making this comparison it is seen the yield in the vanillin plot is as good as in Check B, and the yield in the salicylic aldehyde plot is almost the same as in Check A.

In the unlimed soil with no fertilizers both the vanillin and salicylic aldehyde had a depressing effect on crop growth, but this was not very marked. When the soil was fertilized with sodium nitrate the harmfulness of both compounds was lessened. This was especially so with vanillin, where practically no depression in growth was observed. Acid phosphate also ameliorated the effects of both compounds. In this case salicylic aldehyde had no depressing effects.

On limed soil the effects were noticeable, but their harmfulness was not as much as on the unlimed soil. There were no effects from the aldehydes on the limed soil fertilized with sodium nitrate or acid phosphate.

Examination of the Soil for Aldehydes at the End of the Growing Season.

The soils were examined to determine if the added vanillin and salicylic aldehyde were still present in the soil at the end of the growing period. Twenty pounds of soil were taken from each plot and subjected to the process for the isolation of aldehydes. In 1914 the test showed the presence of aldehydes in only one plot. This was the plot to which salicylic aldehyde had been added on the sodium nitrate section of the unlimed soils. The extracted material from this soil gave the color reactions for aldehydes. This material, when dissolved in distilled water, was harmful to wheat seedlings, reducing growth about 30 per cent.

Notes taken in September showed that the growth on this plot was the poorest in the series, yet at the end of the season this was not especially noticeable.

No reason can be assigned why the aldehyde should persist in this particular plot, while in every other case it was not found to be present.

After the growing season of 1915 no aldehydes could be isolated from any of the plots. Such harmful effects as were observed were probably due to the influence of the added materials at the time and shortly after its application. There were three

applications, the first on July 10, when the seeds were planted, and the last on July 19, when the plants had made considerable growth. If the aldehydes had remained in the soil as such throughout the growing season, the crops would undoubtedly have shown their effects to a much greater extent.

It is rather significant that in the Hagerstown soil, which is a strong productive soil with strong oxidizing power, the aldehydes, when added, did not stay as such, but were destroyed or changed, while in the Arlington soil, which is an unproductive one, with low oxidizing power, the added aldehydes persisted for

FIG. 66.

Turning under green crops to enrich the soil in organic matter. Soil management practised on the Hagerstown loam which induces thorough aeration and oxidation.

months and remained as such throughout the growing season, to have its effect on the crop (Fig. 66).

The nature of this Hagerstown soil seems to be such that organic compounds of the kind added cannot exist for any length of time. Nor could harmful compounds of this nature be formed or remain in this soil. It has been pointed out that the Hagerstown soil has a strong oxidizing power and is otherwise a fertile productive soil. These added aldehydes are undoubtedly acted on in the soil and destroyed or changed to other compounds that are not harmful (Fig. 67).

The contrast between the action of aldehydes in the Arlington soil and in the Hagerstown loam is interesting and demonstrates

that such materials can exist in one soil and have their effect on growth, while in another soil they are destroyed by oxidation or other biological processes of the soil and do not remain for a sufficient length of time to have appreciable influence.

The establishment of the fact that added aldehydes may remain in some soils and disappear in others may explain the reason that in the pot tests with different soils the growth in some was affected by aldehydes and in others it was not. In experiments with the effect of organic compounds in soils, the fact as to whether or not the added material remains as such throughout

FIG. 67.

Showing excellent crops growing on the Hagerstown loam of Pennsylvania, a soil which destroys aldehyde by active oxidative activities.

the growing period should always be demonstrated. To draw conclusions as to the physiological effect of a certain compound without the knowledge of its stability under the conditions of the experiment may lead to erroneous conclusions. Upson and Powel (76) and Funchess (21) were probably working with soils in which the organic substances under study were destroyed, yet they conclude that these materials were not harmful. Davidson's (16) work with cumarin and vanillin would also have been much more valuable if he had examined his soils to establish whether or not the aldehydes remain in the soil.

(To be concluded.)

A PHYSICAL STUDY OF THE WELSBACH MANTLE.*†

BY

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VIII. MANTLES COMPOSED OF OXIDES AND MIXTURES OF OXIDES OF HIGH EMISSIVE POWER IN THE VISIBLE SPECTRUM.

1. Thoria-Ceria.

The series of mixtures of thoria and ceria, in which is included the Welsbach mantle of commerce, is in many respects the most interesting of the mixtures studied. In it are exhibited in striking manner the characteristics of an optimum proportion of the constituents, a fundamental difference in the optical properties of the hot and cold mantle, and a greatly different behavior under different kinds of heating. A full discussion of this series therefore covers many of the characteristics found in others, which can, in their turn, be described briefly in terms of their likeness or unlikeness to the thoria-ceria mixtures.

Gross Physical Characteristics.

Pure thorium oxide, ThO_2, is white, of high reflecting power (85 per cent.), and does not show any color change on heating in a quartz tube in the Bunsen flame. Pure cerium oxide (CeO_2) is either white or brownish white, depending on the method of preparation. Both varieties turn deep yellow or brown in heating to a few hundred degrees, a characteristic which persists in the mixtures of ceria with thoria to very low percentages of the former. It is exhibited clearly in the regular commercial mantle (approximately 1 per cent. ceria) when this is turned low.

* Based on a lecture delivered by Doctor Ives at a meeting of the Section of Physics and Chemistry held Thursday, January 10, 1918. Contributed by the Research Laboratories of the Welsbach Company, Gloucester City, New Jersey.

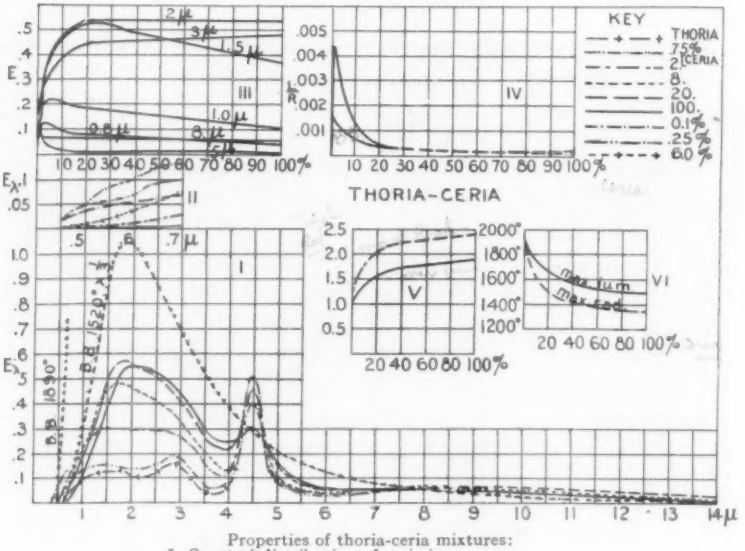
† Concluded from page 438, Vol. 186, October, 1918.

The mantles for study were made of silk. The pure thoria mantles had a weight of 0.009 gramme per cm.^{2}, the pure ceria of 0.0097 gramme per cm.^{2}

Temperature.

The relationship between constitution and temperature is shown in Fig. 16 (VI) for these mixtures. A point of importance appears at once from these curves, namely, the possibility of two adjustments: (1) The adjustment which would be made from

FIG. 16.

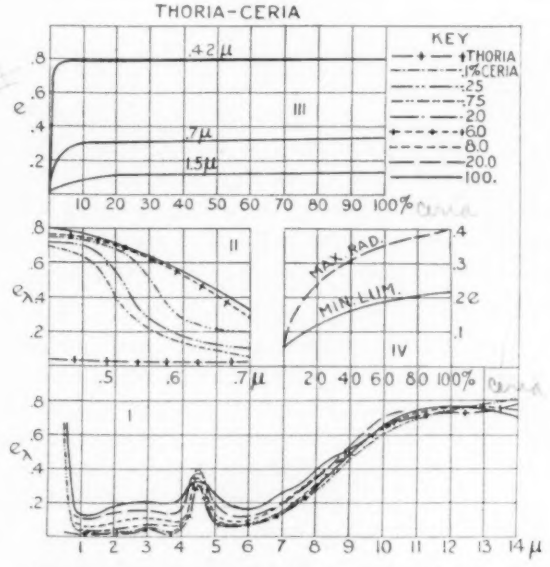


Properties of thoria-ceria mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Emission constitution relation, isochromatics.
IV. Radiant luminous efficiency—constitution relation.
V. Radiance—constitution relation.
VI. Temperature—constitution relation.

the standpoint of light-production—that is, the adjustment of maximum luminosity; and (2) that which would be made if one wished the maximum of radiant heat. The first adjustment is with the flame just inside the mantle; the second is with the flame coming through and enveloping it. In the pure ceria mantle the difference is most striking. As the flame is turned up the mantle gains in brightness until a certain point, when, as the flame strikes through, the light drops off as though quenched by a suffocating gas. This happens first at the top of the mantle,

leaving a bright ring in the bottom, and then with a still larger flame the whole mantle goes dull. As is shown by the curves, and in accordance with the temperature radiation relationship discussed above, the temperature is much lower for the condition of maximum radiation. This different behavior does not appear in the pure thoria mantle, but is a characteristic of the ceria constituent, and will be discussed in greater detail later. The temperature range between the pure thoria and the pure ceria is

FIG. 17.



Emissive power characteristics of thoria-ceria mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution—emissive-power isochromatics.
IV. Total emissive power—constitution relations.

about 400° (1930°–1500°) for the condition of maximum luminosity, and about 600° (1930°–1340°) for maximum radiation. The fall in temperature is most rapid for the low percentages of ceria.

Total Radiation and Emissive Power.

The variation in total radiation with constitution is shown in Fig. 16 (V) for both adjustments, and in Fig. 17 (IV) is given the variation in emissive power.

The radiant emission of the pure ceria mantle is nearly twice that of the pure thoria for the condition of maximum luminosity, and more than twice for maximum radiation. As with the temperature changes, the increase in emission is much more rapid for the smaller admixtures of ceria than later.

The emissive power of thoria, as previously noted, is exceedingly low, about 4 per cent. For the adjustment of maximum luminosity the rise of emissive power is rather gradual, up to 22 per cent. for pure ceria. For maximum radiation it is more rapid for the smaller percentages of ceria, reaching a maximum value of 40 per cent.

Both the behavior of the emission and the emissive power will be analyzed in the discussion of the spectral distribution curves. It is to be noted, as a general criticism of all the emissive power data, both the total and the spectral distribution, that the widely different temperatures and radiating characteristics with various adjustments make the figures given subject to very large possible errors, and the values shown for plotting are not in every case as entirely consistent with each other as could be desired.

Radiant Luminous Efficiency.

In Fig. 16 (IV) is shown the variation of radiant luminous efficiency with constitution. The general characteristic of mixtures of low and high visible emissive powers is shown; namely, the optimum for a certain low percentage of the blacker substance. In this case this maximum efficiency (0.0043) for the whole mantle is over three times that of a black body at the same temperature, the latter being shown by the lower line of the diagram, and occurs for a very small percentage of ceria (0.75 per cent.) and a high temperature (1900°). (For the brightest part of the mantle, through the 1 cm. diameter aperture, the efficiency is about 0.009.) This advantage over the black body persists through all the mixtures, although the difficulty of measuring the very low efficiencies of the ones rich in ceria, and the uncertainty in the corresponding temperatures, prevent a reliable quantitative estimate of the extent of the advantage in their case.

This curve of radiant luminous efficiency merely exhibits the well-known candle-power-ceria content relationship, giving no explanation of the very high value of efficiency attained. The reason for the exceedingly high value is given by the analysis represented in the spectral distribution curves.

Spectral Distribution of Emission and Emissive Power.

The spectral distribution of radiant emission is shown both for the visible and the infra-red regions in Fig. 16 (I and II), while Fig. 16 (III) exhibits the isochromatics or variations of the emission for selected individual wave-lengths.

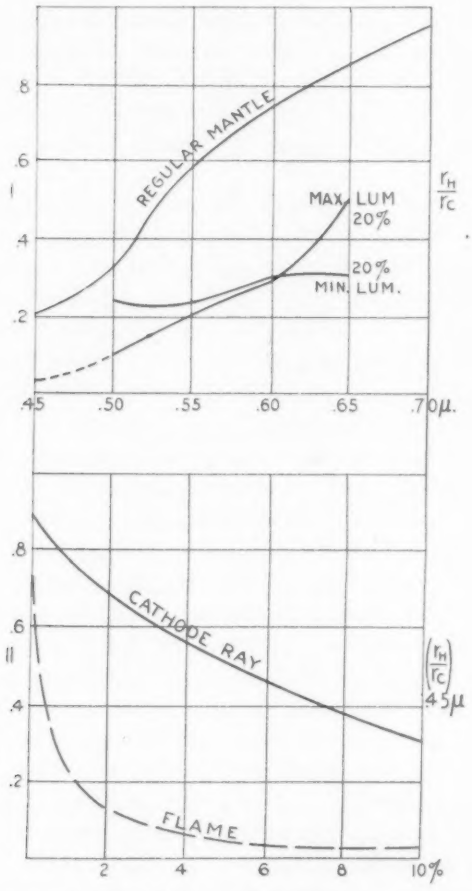
The significant feature of these emission curves is the practically uniform and continuous increase of emission with ceria content in the infra-red region, and its initial very rapid rise to a maximum for 0.75 per cent. ceria and subsequent fall in the visible region. This feature is clearly presented by the isochromatics (III).

When it comes to the emissive power, the behavior is somewhat simpler. Emissive power increases at all wave-lengths with increasing ceria. In this case the significant feature is the rate of increase of emissive power with ceria content at the various wave-lengths (III). While for the infra-red wave-lengths the rise is uniform and gradual for the visible region, and particularly in the blue, the rise of emissive power is very abrupt, reaching saturation for a very low percentage. Not only this, but the actual emissive power attained is very high. As pointed out by Rubens, the ordinary mantle, with its approximately one per cent. of ceria, is practically black for the blue end of the spectrum. This blackness is identical with the yellow coloration on heating, which has already been mentioned. When hot, as shown by the emissive power curves, the ordinary mantle, which is white when cold, becomes deep brown in color. This coloration is due to the occurrence in the hot ceria of an absorption band whose long wave end is comparatively abrupt, and which is almost completely developed with only a small amount of ceria present. This is shown in another way by the ratio of hot to cold reflecting power through the spectrum for a 1 per cent. ceria mantle, Fig. 18 (I). Since the cold mantle is practically white, the hot mantle is thus shown to be strongly yellow.

On the addition of more ceria beyond one per cent., the absorption extends somewhat toward the infra-red, in which region a general absorption also develops. Due to this increased absorbing (emitting) power, the emission increases and the temperature falls. This fall of temperature is at once reflected in the lower emission for the short visible wave-lengths, with the resultant fall in luminosity.

The actual values attained by the emissive powers are, for the most luminous condition, less than 50 per cent., even with pure ceria, except for the visible region, and the very long wave infra-

FIG. 18.



Relationship between hot and cold reflecting power in thoria-ceria mixtures:
I. Behavior in different parts of spectrum.
II. Behavior of various mixture proportions in the flame and under cathode-ray bombardment.

red beyond 9μ, where saturation is again approached. There is thus a region of low emissive power centering around 4μ which, as will be seen, occurs in most of the oxides.

Behavior in Different Parts of the Flame.

The fact that ceria has a different emissive power in the oxidizing and reducing flame was noted by Féry[8] in 1903, and he built largely upon this fact a theory that the efficiency of the mantle is to be explained by the highly emitting ceria in a reducing condition, imbedded in thoria, which is poorly emitting in the same condition. This theory is inadequate, for it does not take into account the different spectral distribution of emissive power of the two constituents, which is really the dominating factor, and, moreover, in the ordinary mantle burner the flame is *oxidizing* on the outside, not reducing. It is only when the flame is made so full as to envelop the mantle that the latter is subject to reducing conditions.

With a view to determining more specifically the change in character occurring in going from one type of flame to another, a supplementary set of spectral emission curves was made, and also some experiments on fragments of mantle heated in the interior of the flame and cooled in a reducing atmosphere.

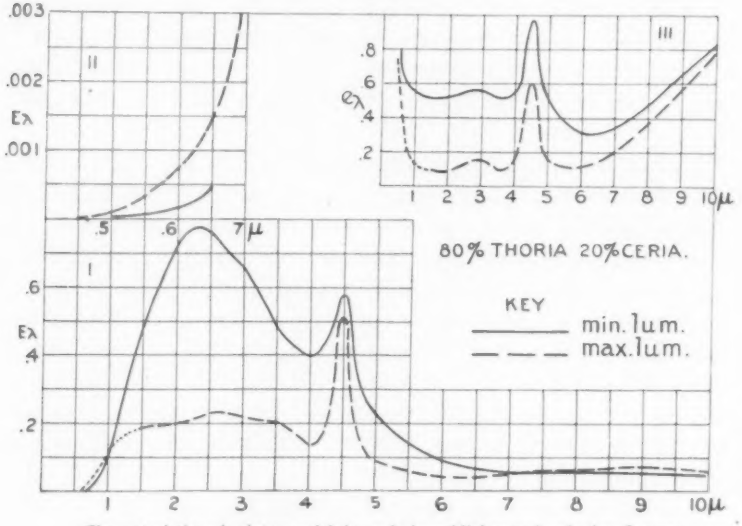
The emission curves were made on a mantle of 80 per cent. thoria and 20 per cent. ceria composition, which exhibited the characteristic behavior excellently. Extreme conditions of the flame were taken so that the results do not form part of the same series as the curves already shown. The oxidizing and reducing flame emission curves are shown in Fig. 19 (I and II), and the corresponding emissive power distributions in Fig. 21 (III), while in Fig. 18 (I) are exhibited the changes of reflecting power in the visible region for the two kinds of heating. It is evident from these curves that not only is the emissive power in the reducing flame much higher, but it is less selective. The mantle approximates *gray* rather than brown, as is well shown by the hot and cold reflecting powers, where the very great drop in reflecting power in the blue, which is characteristic of ceria in the ordinary mantle, is greatly decreased.

This conclusion is supported by the experiments on heating a fragment of the mantle in the inner part of a Meker burner flame, which is practically free from oxygen (less than 0.1 per cent.), and removing the fragment through a quartz tube inserted in the flame, so that it cools in the products of combustion. The fragment thus treated comes out *dark gray*. Furthermore, if it is heated in hydrogen it turns *black*. In either case, upon heating in

the oxidizing flame the mantle material at once reassumes its ordinary color.

The various changes gone through by ceria on heating are probably to be ascribed to the formation of several different oxides, for whose existence there is other evidence. The ordinary is CeO_2, the yellow formed on heating in the oxidizing flame is perhaps CeO_3, the gray or blue [9] formed in the reducing flame Ce_4O_7.

FIG. 19.



Characteristics of mixtures rich in ceria in oxidizing and reducing flames:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Spectral distribution of emissive power.

Behavior in the Cathode Discharge Tube.

A question long outstanding has been why the Welsbach mantle, and the materials composing it, behave altogether differently when heated in the flame and when heated by the bombardment of cathode rays. Campbell-Swinton,[10] in 1899, performed the experiment of heating a composite "mantle" composed of sectors of pure thoria, pure ceria, and the Welsbach mixture in a cathode-ray tube. He found two striking differences between the behavior of the mantles there and in the flame. First, the 99 per cent. thoria and 1 per cent. ceria mixture gave no more light than the pure thoria. Second, while the pure thoria gave a vivid incandescence, the pure ceria gave scarcely any light; in the

flame the light given by pure thoria and pure ceria is not greatly different in intensity, although very different in color.

In order to repeat this experiment, use was made of the cathode-discharge tube already described, Fig. 2, and some four-part disk mantles of the design shown in the same figure, one of the sectors being pure thoria, one pure ceria, one 99 per cent. thoria and 1 per cent. ceria, and the fourth, 90 per cent. thoria and 10 per cent. ceria. On subjecting these to the cathode discharge the behavior described by Swinton was observed, the luminosity being greatest for the thoria, which gave a brilliant light, and decreasing according to the amount of ceria, the pure ceria giving only a dull glow. After continued bombardment the pure thoria sector was apparently unchanged, while those containing ceria became darkened to a bluish-gray. On heating in air this darkening disappeared, restoring the mantle to its original appearance. This darkening is thus ascribable to the well-known reducing action of the cathode discharge.

It was suspected that the failure of a small admixture of ceria to enhance the luminosity of the thoria was due to the failure to develop the strong visible absorption band, to which, as has been pointed out, is chiefly due the efficiency of the flame-heated mantle. In order to test this hypothesis a series of measurements were made of the ratio of hot to cold reflecting power for blue light (0.45 μ), both in the cathode discharge and in the flame. The results are shown in Fig. 18 (II). It is evident at once that the great increase of absorbing power conferred by the small addition of ceria to the thoria in the flame, is largely inhibited in the cathode discharge. Whereas, the blue reflecting power for one per cent. of ceria drops to 20 per cent. of its cold value on flame heating, it only falls off a matter of ten per cent. in the discharge tube. At the same time, as was shown by the experiments on heating in the reducing flame, a reducing condition increases the general emissive power of ceria, so that the effect of ceria in reducing the mantle temperature is favored in the discharge tube. The net result of thus inhibiting the selective absorption in the blue and increasing the general absorption is to quite destroy the merits of ceria as a coloring agent for thoria. More than that, while the ceria is in its most completely radiating condition when it assumes the lowest temperature, thoria, which, according to the work of Féry, has its lowest emissive power in the reducing flame,

is probably also assuming a relatively higher temperature in the cathode discharge, whereby its luminosity is enhanced. Consequently the approximate equality of the ceria and thoria mantles in the oxidizing flame is no longer present in the cathode discharge. This behavior is not the complete explanation of this great difference in luminosity, which will be more fully treated when the question of convection and conduction losses is taken up.

Behavior in a Vacuum and in a Hydrogen-chlorine Flame.

Realization of the importance of the oxidizing condition led to trials of the effect of heating the mantle in the entire absence of oxygen. First the experiment was tried of heating ceria in a quartz tube which was connected with a pump and maintained at a high vacuum. It was thought that under these conditions the ceria might not show the characteristic yellowing. The experiment showed, however, that the usual yellowing took place.

Next a special mantle was made up divided vertically into two parts, one pure thoria, the other the regular mantle mixture. This was heated by a hydrogen flame burning in air under a bell jar, from which the air was then displaced by chlorine gas. A similar experiment was performed by Killing [11] to test the alternate oxidation and reduction theory of Auer, but his object was merely to determine whether the mantle became incandescent and not whether the coloring action of ceria was present. Our experiment showed clearly that the relative brilliancy of the thoria and thoria-ceria mixtures was little, if any, affected by the change from air to chlorine.

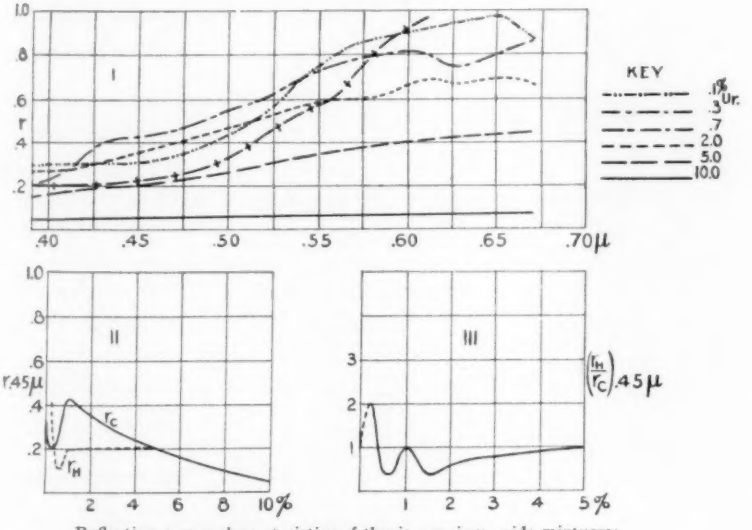
It appears from these two experiments that mere absence of oxygen is not sufficient to prevent the ceria from turning yellow and so coloring the mantle. An actual actively reducing condition, such as the cathode discharge tube, is essential. Even the reducing region of the Bunsen burner, although it causes the large drop in temperature and luminosity already noted in pure ceria, does not noticeably affect detrimentally the behavior of the regular mantle mixture. It thus appears that the absorption band in the blue region and the general absorption through the infra-red behave as though due to separate mechanisms. The latter is rather easily increased by a non-oxidizing condition; the former is only inhibited by a very strongly reducing one.

2. *Thoria-uranium Oxide.*

Physical Characteristics and Behavior in General.

Of all the mantle mixtures studied, those of uranium oxide with thoria show the nearest approach in efficiency to the regular Welsbach mantle. The approach is, however, only to about 50 per cent. of that efficiency. In some other respects, however, uranium oxide is even more interesting than ceria in its coloring action.

FIG. 20.

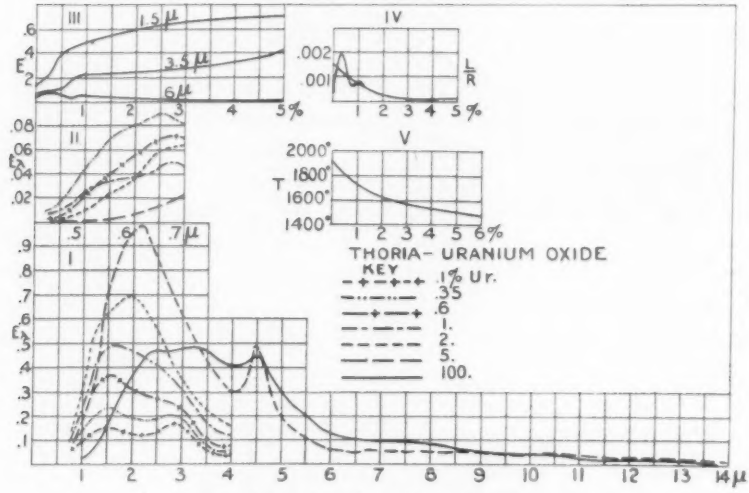


Reflecting-power characteristics of thoria-uranium oxide mixtures:
I. Spectral distribution, visible region.
II. Reflecting-power-constitution relation for 0.45 μ.
III. Ratio of hot to cold reflecting power at 0.45 μ for mixtures from 0 to 5 per cent. uranium oxide.

Uranium oxide itself is a deep brown, nearly black substance, which cannot be made up into a well-shaped mantle. As it is mixed with thoria the mixture is progressively lighter brown in color, until at about 7 per cent. uranium oxide, where it is nearly white, the mixture starts to assume a lemon-yellow color, which is at a maximum near 0.35 per cent., after which the yellow becomes paler until the white of pure thoria is reached. This series of changes is shown in the spectral reflecting power curves of Fig. 20 (I) and more clearly in the isochromatic reflecting power constitution curve of Fig. 20 (II) for 0.45 μ.

A further interesting property of this lemon-yellow coloration is found on examining the relation of hot to cold reflecting power at 0.45 μ as shown in Fig. 20 (III). On applying this ratio to the cold reflecting power isochromatic, thus obtaining approximately the hot reflecting power behavior with varying concentration, it is seen that the maximum absorption is shifted to a higher percentage of uranium oxide. Thus, while the maximum coloration cold is about 0.35 per cent., it is about 0.7 per cent. hot.

FIG. 21.



Characteristics of thoria-uranium oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Emission-constitution isochromatics.
IV. Radiant luminous efficiency-constitution relation.
V. Temperature-constitution relation.

This absorption band has much in common with the band developed in the same region by ceria, and, like it, is responsible for the comparatively high luminous efficiency attained.

Considerable difficulty was experienced in obtaining consistent results in the visible spectrum with the uranium oxide mantles, due to the somewhat transient character of the yellow coloration. It appears either to volatilize, leaving the mantle streaked, or to be dependent on the oxidizing or reducing character of the flame at the time of extinguishing. Like the ceria coloration, it is inhibited by the reducing condition of the cathode discharge, in

which the most efficient thoria-uranium oxide mixture shows no advantage over pure thoria.

Temperature and Total Radiation.

The drop in temperature produced by adding uranium oxide to thoria is much more rapid than the drop due to ceria. It is shown for the first 5 per cent. addition in Fig. 21 (V). Already for only 5 per cent. the temperature is reduced to 1500°, where with ceria in the reducing flame the corresponding drop is only to about 1700°. The total radiation is fixed approximately, in accordance with the relationship shown in Fig. 10 (I), by the temperatures.

Radiant Luminous Efficiency.

The relationship between constitution and radiant luminous efficiency shown in Fig. 21 (IV) is unique among the mantles studied in showing two maxima. The first of these occurs at about 0.35 per cent. uranium oxide, the second at about 1 per cent. They are obviously connected, as is borne out by the spectral distribution, the first with the transient yellow coloration, the second with the steadily increasing brown coloration. Due to the latter alone, this series of mixtures would be similar to the ceria mixtures and others to be treated later. The maximum efficiency (0.0008) would be only slightly over that of a black body at the same temperature. The initial yellow coloration gives an efficiency (0.002), more than half as much again as the black body at the same temperature (lower light line), and this temperature, because of the small general emission for this concentration (0.35 per cent.), is quite high.

Spectral Emission and Emissive Power Distribution.

These are shown in Figs. 21 (I, II, and III) and 22 (I, II, and III), which are largely self-explanatory. The emissive power in the infra-red rises much higher than for ceria, in agreement with the temperature data, and exhibits a steady increase with concentration. In the visible region the emissive power and the emission show the characteristic maximum at 0.35–0.50 per cent., the emissive power continuing to rise after passing through the minimum at 0.8 per cent., the emission rising slightly, but then falling off because of the drop in temperature. The very irregular character of the isochromatics (III) is probably in part due to

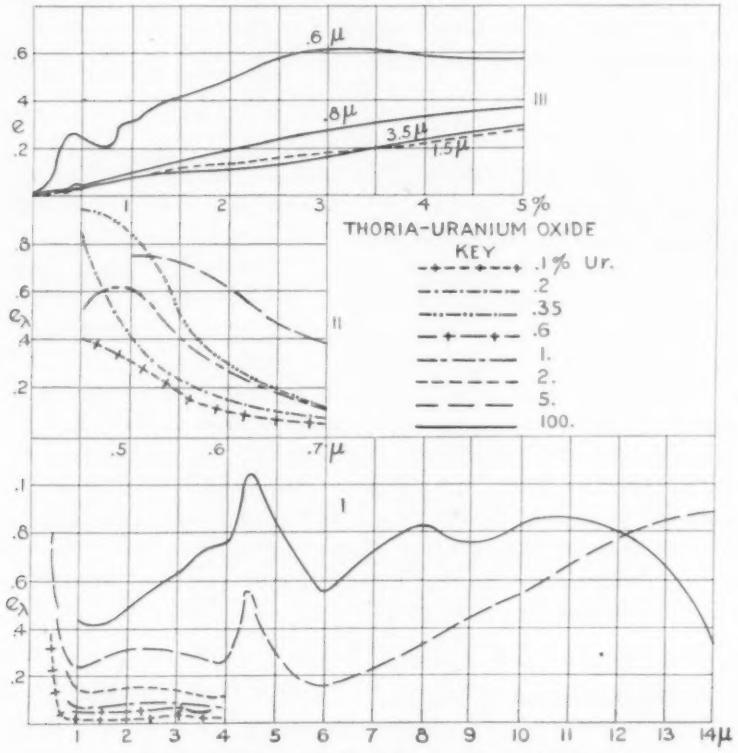
the difficulties of exact measurement introduced by volatilization, already noted.

3. *Thoria-manganese Oxide.*

Physical Characteristics and Behavior in General.

Manganese oxide behaves much as uranium would were it not for the latter's anomalous behavior in the region where it shows

FIG. 22.



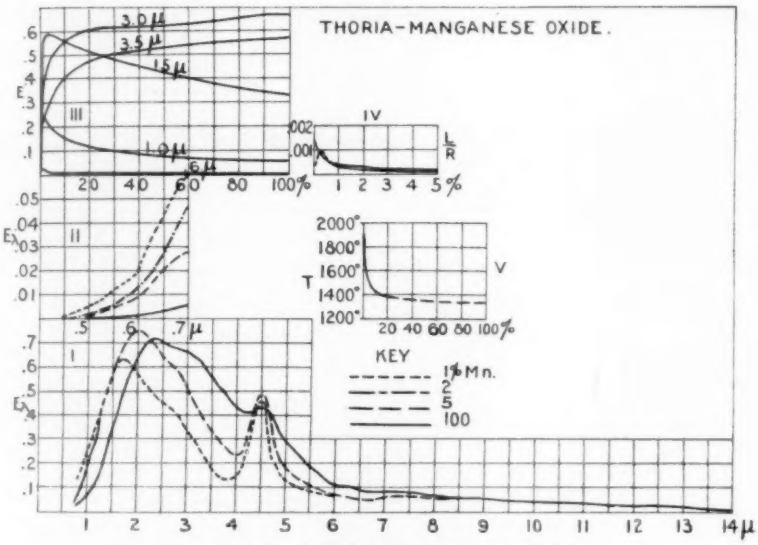
Emissive-power characteristics of thoria-uranium oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Emissive-power-constitution isochromatics.

the lemon-yellow coloration. Manganese oxide is dark brown, nearly black in color, and its mixtures with thoria show a regular progression of color down to the white of the latter.

Perhaps the feature of most interest displayed by manganese is its tendency to decolorize on heating, thus being opposite in

behavior to ceria, although the amount of the effect is much less. It is exhibited by the ratio of hot to cold reflecting power, which is 1.35 for wave-length 0.55 μ for 100 per cent. manganese oxide. It is also shown in a very striking manner by moving a thoria-manganese oxide mantle from the outside to the inside of the Bunsen flame. On the outer edge of the flame the mantle is dull; inside it glows brilliantly, thus being exactly opposite in behavior

FIG. 23.



Characteristics of thoria-manganese oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Emission-constitution isochromatics.
IV. Radiant luminous efficiency-constitution relation.
V. Constitution-temperature relation.

to ceria. The visible decolorizing is apparently produced by the oxidizing flame. It is possible, also, that a decrease of infra-red emissive power is brought about by the reducing flame.

Temperature and Efficiency Characteristics.

The variation of temperature with concentration, Fig. 23 (V), is of the same character as with uranium and of nearly the same magnitude.

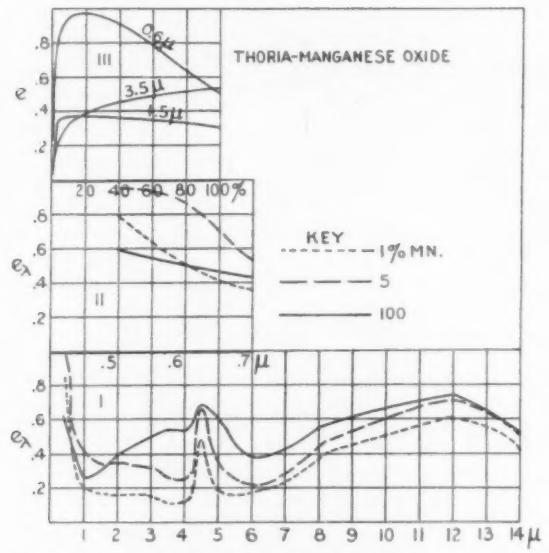
The radiant luminous efficiency, as shown in Fig. 23 (IV), goes through the maximum characteristic of mixtures with thoria

of substances of relatively high visible emissive power. The highest efficiency attained 0.0009, for 0.25 per cent. is, however, only slightly above the black body at the same temperature (light line), and, while for higher concentrations the advantage over the black body is greater, the decreased temperature reduces the efficiency to insignificant values.

Spectral Emission and Emissive Power Distribution.

These are exhibited in Fig. 24, which is self-explanatory. As in the case of uranium, a high visible emissive power, comparable

FIG. 24.



Emissive-power characteristics of thoria-manganese oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution-emissive-power isochromatics.

to that of ceria, is of small value for light-production because of the large amount of general infra-red absorption. The isochromatics show clearly the whitening which sets in in the visble region with higher concentrations of manganese.

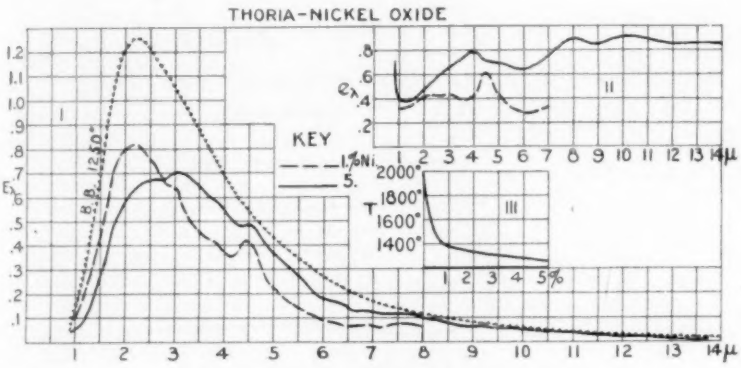
4. *Thoria-nickel Oxide.*

Nickel belongs with a group, which includes cobalt, chromium, and vanadium, upon which very little time was spent, because of

the small interest from the standpoint of light-production. In each case the total emissive power is large, resulting in a rapid drop of temperature for quite low admixtures with thoria. They exhibit the characteristic increase of luminous efficiency over thoria for small admixtures, but this increase is not in any way comparable with that shown by uranium or cerium.

The spectral emission and emissive power curves for 1 per cent. and 5 per cent. nickel are shown in Fig. 25 (I and II). The corresponding temperatures are 1250° and 1360° K. (IV). Nickel oxide is, of all substances measured, the blackest, having

FIG. 25.



Characteristics of thoria-nickel oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emissive power.
III. Constitution-temperature relation.

for 5 per cent. already a higher emissive power than pure cerium or uranium oxide. The blackness of the visible region of the thoria-nickel mixture is increased by the reducing cathode-discharge bombardment.

5. *Thoria-lanthanum Oxide.*

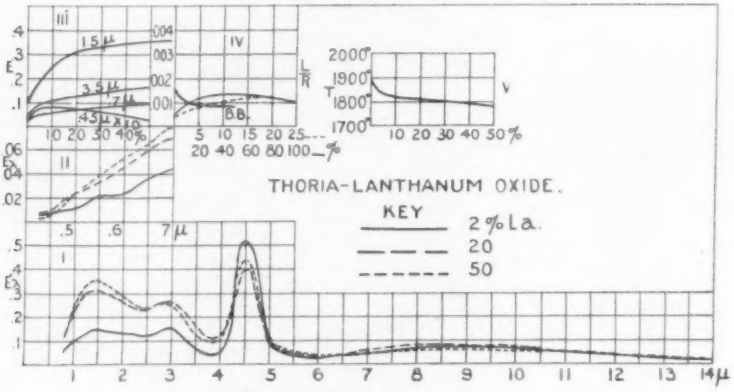
Lanthanum is of peculiar interest because, while a single oxide, it exhibits the spectral distribution of emissive power and the changes between the hot and cold states characteristic of the thoria-ceria mixture, not, however, to nearly so useful an extent. When cold, lanthana is, if dry, white. On standing it takes up water, swells, and assumes a brownish tinge. It is too fragile, after thus standing, for use as a mantle. The majority of the

measurements made were confined to mixtures with thoria up to 50 per cent., because the higher percentages of lanthana would not hold together long enough.

Temperature Characteristics.

In Fig. 26 (V) is shown the temperature-concentration relation. It will be noted that the temperature is pulled down very much less rapidly by lanthanum than by any of the oxides thus far studied. The drop in temperature is, however, quite rapid for the first 5 per cent. addition.

FIG. 26.



Characteristics of thoria-lanthanum oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Constitution—emission isochromatics.
IV. Radiant luminous efficiency—constitution relation.
V. Constitution—temperature relation.

Radiant Luminous Efficiency.

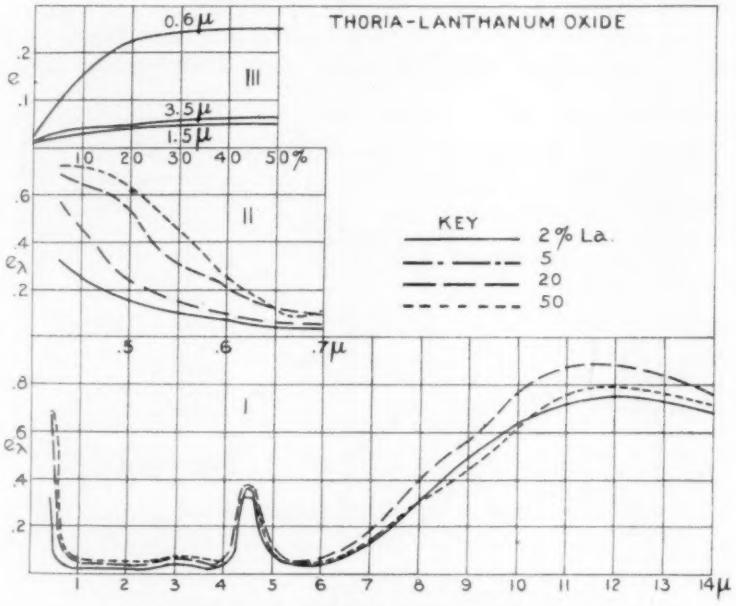
The variation of radiant luminous efficiency with concentration is shown in Fig. 26 (IV). We have here the usual optimum occurring, but, unlike all the others so far, the optimum is not for very small percentages, but near the 50 per cent. point. The reason for this is evident when it is noted that the efficiency of pure lanthana is more than twice that of pure thoria, whereas in all previous cases the efficiency of the pure colorant has been below that of thoria, and the temperatures they assume very much lower than that assumed by lanthana. The behavior of lanthanum oxide is easiest described by noting that it might be replaced by a definite mixture similar in many respects to a thoria-ceria one.

containing about twice as much colorant as enough to give the maximum efficiency.

Spectral Emission and Emissive Power Distribution.

These are shown for 2, 20, and 50 per cent. lanthana in Fig. 26 (I, II, and III) and Fig. 27 (I, II, and III). The noteworthy similarity with the thoria-ceria mixture is evident. From the

FIG. 27.



Emissive-power characteristics of thoria-lanthanum oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution-emissive-power isochromatics.

emissive power curve it is seen that when hot this substance develops an absorption band in the visible region, just as does the ordinary Welsbach mantle. This band and the yellowing due to standing in the atmosphere are undoubtedly allied. Unlike ceria, however, this visible absorption band only assumes considerable values for high concentrations of lanthana, with which is associated sufficient general infra-red emission to pull the temperature down below the useful point.

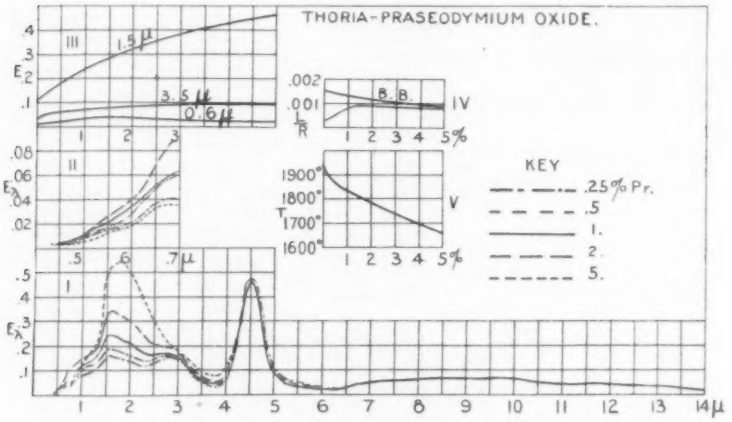
6. *Thoria-praseodymium Oxide.*

Mixtures of thoria with neodymium and praseodymium present a number of interesting phenomena, which, properly interpreted, must undoubtedly throw some light on the chemical relationship of the two and on the nature of the mechanism which produces their peculiar spectra. For reasons which will appear, they must be considered in the relation to each other, and, for simplicity's sake, the first one to describe is praseodymium.

General Physical Characteristics and Behavior.

Praseodymium oxide (Pr_4O_7) is dark brown or black. With thoria it gives dark brown mixtures, even when present only to

FIG. 28.

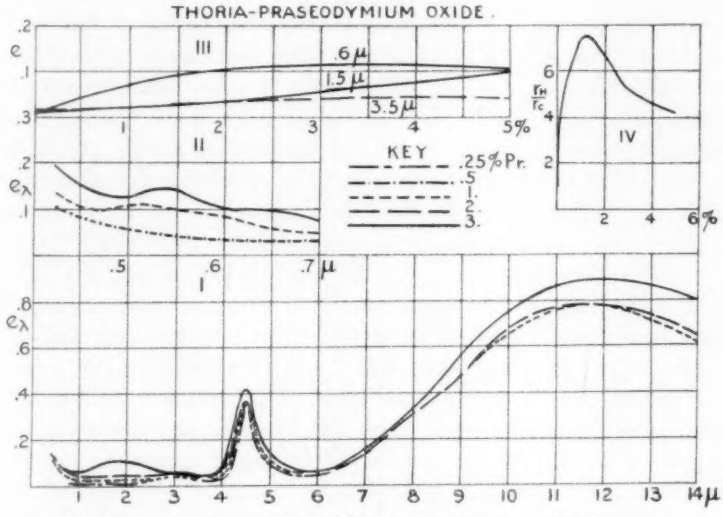


Characteristics of thoria-praseodymium oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Constitution-emission isochromatics.
IV. Radiant luminous efficiency constitution relation.
V. Constitution-temperature relation.

the amount of a fraction of one per cent. This brown is, however, a function of the state of oxidation. When heated anywhere, except at the extreme outer edge of the flame (where it is most brilliant), it whitens, as is shown clearly by the ratio of hot to cold reflection power in Fig. 29 (IV) for wave-length 0.45 μ. It appears from this that for one per cent. of praseodymium, where the effect is a maximum, the increase in reflecting power on heating is no less than six times. This phenomenon is again demonstrated by withdrawing a mantle fragment from the in-

terior of the reducing flame, from which it emerges white; by subjecting it to the cathode discharge, with the same effect, and finally by heating the oxide in a stream of hydrogen. This latter experiment is commonly reported as furnishing a *green* lower oxide. With the praseodymium used for this work, which was obtained from 4380 fractional crystallizations and used by Baxter in his atomic weight determination, the product is *white*.

FIG. 29.



Emissive-power characteristics of Thoria-praseodymium oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution-emission isochromatics.
IV. Ratio of hot to cold reflecting powers for wave-length 0.45 μ for various proportions of praseodymium.

Temperature and Luminous Efficiency.

The temperature composition plot of Fig. 28 (V) shows that praseodymium pulls down the mantle temperatures about as does ceria in its condition of maximum emissive power.

From the plot of radiant luminous efficiency against composition (IV) it is seen that the maximum efficiency never attains that of a black body at the same temperature.

Spectral Emission and Emissive Power Distribution.

These are shown in Fig. 28 (I, II, and III) and Fig. 29 (I, II, and III). The most striking point is the low visible

emissive power, due to the whitening process, by reason of which is the failure, just noted, to attain a reasonable efficiency.

7. *Thoria-neodymium Oxide.*

Physical Characteristics and Behavior in General.

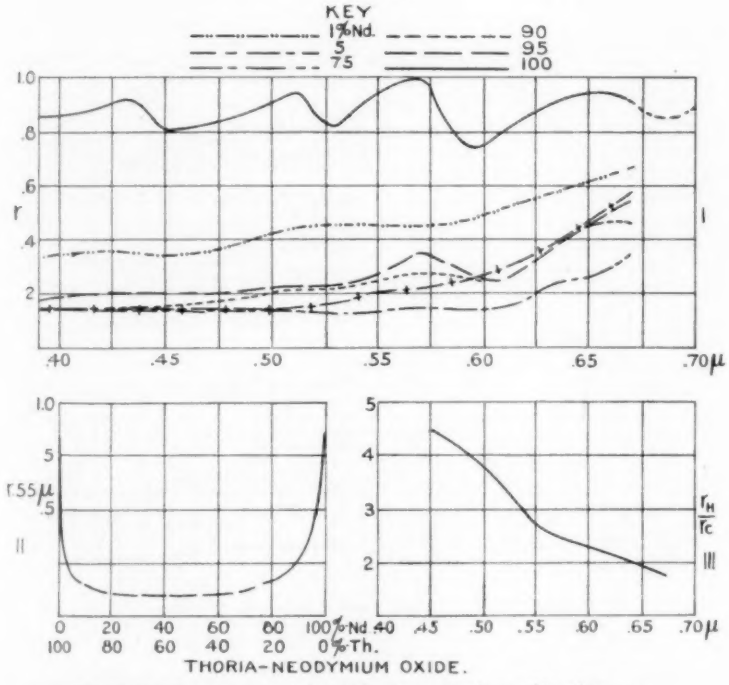
Neodymium is of extreme interest in optics from the fact that the absorption and emission bands of practically all its compounds are of extreme narrowness and sharpness. In the vast majority of solids, particularly the oxides, the absorption bands are wide and diffuse, with no well-marked beginning or end in the spectrum. This is true, as has just been seen, even with praseodymium, which is closely allied with neodymium. From the standpoint of light-production, neodymium oxide is of exceptional interest because its sharply defined absorption bands exemplify the kind of absorption which would be postulated for an ideal coloring material to be added to thoria in place of the somewhat extended absorption of the ceria band, narrow as that is.

Pure neodymium oxide, when freshly reduced, has a pinkish-white color, due to the presence of strong, narrow absorption bands in the green and yellow-green. On long heating this pink changes to a blue tinge, and the absorption band in the yellow-green spreads out into a multiple band in the yellow. Still another form, light brown in color, may be formed under certain conditions. Thus, if the pinkish oxide is gently heated in a quartz tube, through which air may pass, it turns to brown. A pure neodymium oxide mantle which had been laid aside for several months was found to have turned to this brown form, to return to grayish or bluish white, on igniting. The brown oxide formed by gentle heating in the manner described is reduced to the blue-gray form by contact with the reducing flame. The spectrum of this brown form appears continuous in a small spectroscope.

This brown coloration has been variously ascribed to impurities (*e.g.*, praseodymium) and to the formation of a hydrated oxide. The latter appears the more likely from our observation. At any rate, the occasional brown appearance of the pure oxide plays no apparent part in its radiating characteristics, as it is so entirely destroyed by the kind of heating a mantle gets in a flame. It is chiefly dwelt on here because of its possible connection with the extraordinary color phenomena exhibited by the thoria-neodymium mixtures, to be described next.

When neodymium oxide, which is only slightly off white, is mixed with thorium oxide, which is pure white, all the mixtures except those very close to the extremes of the series are *deep brown* in color, appearing, and, as will be seen, behaving, very much like the mixtures of thoria with praseodymium. In this brown mixture the typical banded spectrum of the neodymium disappears.

FIG. 30.



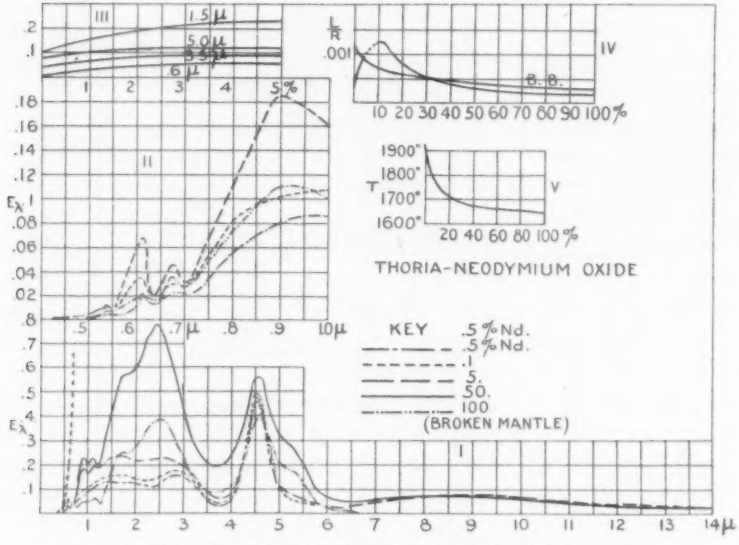
Reflecting-power characteristics of thoria-neodymium oxide mixtures:
I. Spectral distribution of reflecting power (in terms of MgO = unity).
II. Reflecting-power-constitution isochromatic for 0.55 μ.
III. Ratio of hot to cold reflecting power through the spectrum for a 5 per cent. neodymium oxide 95 per cent. thoria mixture.

This phenomenon is illustrated in detail by the spectral reflecting power curves (in terms of MgO as unity) of Fig. 30 (I). It will be noted that the banded spectrum of the neodymium is, as it were, buried by the general absorption which gives the brown color. Fig. 30 (II), showing the variation of reflecting power with composition at wave-length 0.55 μ, exhibits the behavior even more graphically. It is remarkable that the addition of five per

cent. of white thoria to 95 per cent. of nearly white neodymium oxide should result in a deep brown substance.

On heating these brown mixture mantles in the flame they are unchanged, judged by their appearance upon cooling, thus differing from the brown color sometimes shown by pure neodymium oxide. White hot, however, our measurements show that the brown coloration quite disappears. This is shown in one way by the ratio of hot to cold reflecting power through the spectrum for

FIG. 31.



Characteristics of thoria-neodymium oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, short-wave region.
III. Constitution-emission isochromatics.
IV. Radiant luminous efficiency-constitution relation.
V. Constitution-temperature relation.

the 5 per cent. neodymium mixture, Fig. 30 (III). This ratio is obviously nearly complementary to the cold reflecting power, showing the elimination, while hot, of the special brown color. The spectral distribution curves show this quite clearly to be the case.

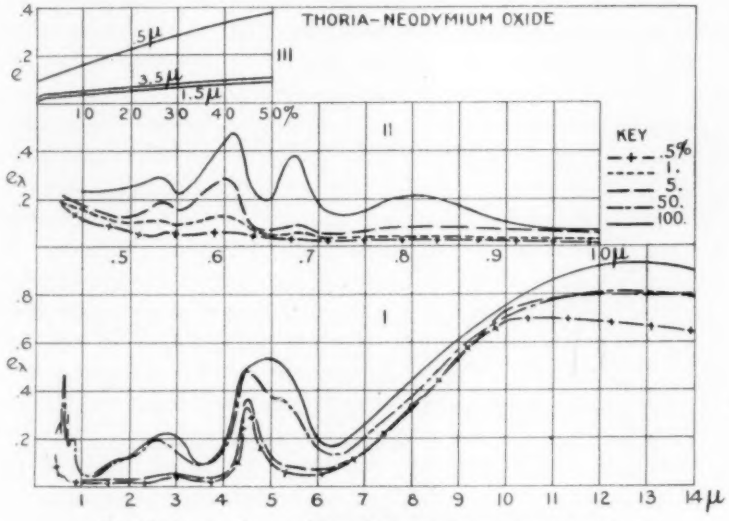
On heating in the cathode discharge, the brown mixtures behave just as the praseodymium mixtures; that is, they turn white, leaving the neodymium bands, and on heating in the air the brown color returns. Similarly, on heating inside the Bunsen

flame and withdrawing, the brown color is destroyed, until reheating is done to the oxidizing flame.

Temperature and Radiant Luminous Efficiency.

These are exhibited in Fig. 31 (IV and V). The temperature drop is not excessive, being much less than for ceria. The radiant luminous efficiency rises to nearly double that of the black body at the same temperature, and as in the case of lanthanum, though

FIG. 32.



Emissive-power characteristics of thoria-neodymium oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, short-wave region.
III. Constitution-emissive power isochromatics.

not so conspicuously so, the maximum occurs for a fairly high percentage of neodymium admixture; namely 5 per cent., when the efficiency is 0.0013.

Spectral Distribution of Emission and Emissive Power.

These are shown in Fig. 31 (I, II, and III) and Fig. 32 (I, II, and III). The striking characteristics of these are, first, the narrow emission bands shown not only in the visible spectrum, but in the infra-red; and, second, the banded character in the visible spectrum, and the regular progression, from low to high neodymium percentages, of the emissive power in the visible

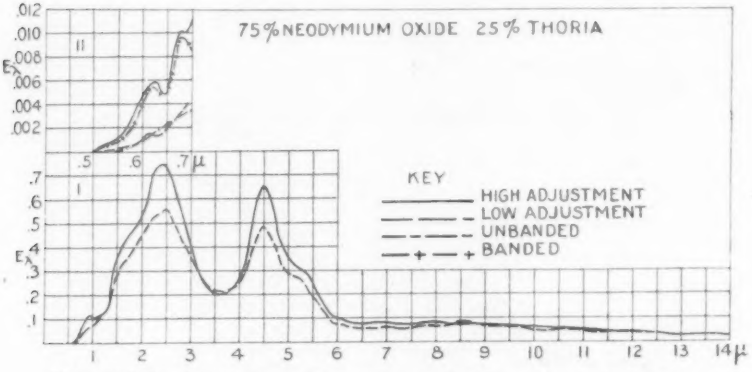
region. This latter clearly shows the destruction of the brown coloration in the hot mantle, in which the various mixtures exhibit intermediate properties between those of the ends of the series.

The emission bands peculiar to neodymium oxide have their maxima, as determined from the emission curves, at 0.54 μ, 0.612 μ, 0.675 μ, 0.92 μ, 1.12 μ, 1.75 μ, 2.2 μ, 2.42 μ, 5.25 μ.

Behavior in Different Kinds of Flames.

The whitening effect of the ordinary flame and the reducing flame have already been noted. An experiment connected with the same phenomenon is illustrated by Fig. 33 (II), in which,

FIG. 33.



Characteristics of neodymium oxide mixtures with different flame adjustments:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.

using a 75 per cent. Nd, 25 per cent. Th mantle, the flame was turned quite low, with the result (unbanded curve) that *the characteristic visible emission bands disappeared.* The emission spectrum is, in fact, of the character to be expected from a brown radiator.

This unbanded spectrum was no longer possible to produce after the mantle had been burned for some time, as is indicated by the second set of curves shown, marked "High and low adjustment." The infra-red measurements made after the mantle had lost its original characteristics to some extent are shown in Fig. 33 (I), in which, nevertheless, a decrease in the near infra-red banded structure is still apparent.

Similarity of Neodymium and Praseodymium in Mixtures with Thoria.

From the data shown it is to be seen that the mixtures of neodymium and praseodymium with thoria have many points of similarity. They show the same color and kind of spectrum. They both whiten in reducing conditions. They might, in short, be mistaken for each other, especially in the lower percentages where the whitened neodymium mixtures show the neodymium bands only very slightly.

The suggested explanations noted above for the brown coloration of neodymium oxide—namely, that it contains praseodymium as an impurity, or is hydrated—appear inadequate for the present case. The amount of praseodymium present in the neodymium oxide used is believed to be less than 1 per cent., so that the 5 per cent. mixture, which is deeply colored, would have less than 1/20 per cent., and this quantity of the pure praseodymium scarcely colors the thoria at all. A coloration of neodymium oxide due to the presence of cerium has been previously noted by other workers, but was explained as actually due to praseodymium, for which the cerium was acting as an oxygen carrier. It appears from this present work that the occurrence of the brown mixture, with its continuous spectrum, is less likely to be due to impurity, particularly praseodymium, than to an altered configuration of the atoms. Further study of this point would be of great interest as possibly throwing light on the structure of the atoms of the neodymium compounds.

One observation made in obtaining the praseodymium mixture curves may be recorded, although it has not been repeated; namely, the appearance under one condition of adjustment of the shorter infra-red bands characteristic of neodymium.

8. *Thoria-eribium Oxide.*

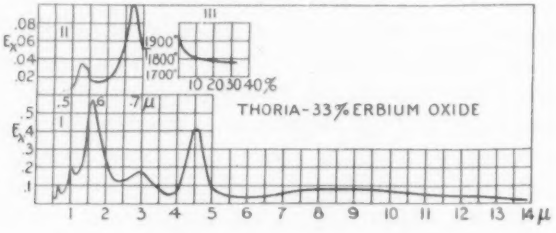
Complete measurements were made on only one mixture of erbium and thorium—namely, 33 per cent. erbium oxide—tests on a small sample of oxide having indicated that only in large percentages would the visible absorption bands of erbium oxide be broad enough to be of any promise for coloring.

Temperature measurements were made on this mantle and on a series of regular thoria-ceria mantles, to which had been added 1, 2, and 5 per cent. of erbium oxide in an experiment to see if

the visible erbium band would add anything of value to the ceria band. These temperature points are shown in Fig. 34 (III). The general emissive power of erbia is low, resulting in a low temperature drop. The net result of adding erbia to the regular mantle, in spite of its small effect on the temperature, is a reduction in efficiency.

Spectral distribution curves of emission and emissive power are shown in Fig. 34 (I, II, and III). The narrow emission bands, similar in character to those of neodymium, are too narrow in the visible spectrum to aid substantially in light-production, and are offset by similar bands in the near infra-red.

FIG. 34.



Characteristics of thoria-erbium oxide mixtures:
I. Spectral distribution of emission, 33 per cent. erbia; 67 per cent. thoria.
II. Same, visible region.
III. Constitution-temperature relation.
IV. Spectral distribution of emissive power.

9. *Other Oxides.*

Besides the oxides for which data have been given, a number of others were investigated, which, for one reason or another, it did not appear profitable to attempt to measure in mantle form. Among them may be mentioned Barium, Cadmium, Calcium, Iron, Molybdenum, Strontium, Titanium, Tungsten, and Zinc, which exhibited volatilization or other defects.

Mention should be made also of platinum, which, applied in the form of a spray of platinic chloride, greatly increases the efficiency of the thoria mantle, but volatilizes so rapidly as to defy measurement and use.

10. *General Summary on Oxide Mixtures.*

It is shown by the data on the various mixtures of coloring oxides with thoria that their behavior is in general the same, differing, however, greatly in degree. In all cases an optimum mixture proportion is found. The value of the luminous efficiency

at the optimum is greatest for ceria, below which come uranium oxide and neodymium oxide, both exhibiting an efficiency notably above the black body. The other oxides have at their optimum mixtures efficiencies too low to be of much interest.

The comparatively high efficiency of both the cerium and uranium oxides is due to the presence of a strong absorption band in the blue end of the visible spectrum. In the case of ceria this band is present only when the oxide is hot; in the uranium oxide it is present also in the cold condition. Other oxides—namely, manganese and praseodymium—bleach when hot, thereby partly losing their visible absorption bands, with consequent low efficiency.

It appears to be a general characteristic of all the coloring materials to rise in emissive power in the visible spectrum, indicating that the absorption bands, which give visible coloration, have their centres in the ultra-violet region. This is in agreement with their integral visual color, which is never blue, but always yellow or brown. To this is to be added the very general relative transparency in the infra-red from 1 μ to 5 μ. Both of these characteristics may be to some extent due to the mechanical structure of the mantle. Thus a roughened transparent substance, such as a piece of ground rock-salt, ceases to scatter light when the wave-length becomes long compared to the magnitude of the separate surfaces constituting the roughening; that is, in the infra-red. Also, the absorbing, or scattering, effect of small particles, in which state the coloring material may be present, decreases with increasing wave-length.

One of the most interesting facts brought out by the data is that the color characteristics of mixtures are not always simply additive. This is exemplified by the extraordinary behavior of the neodymium mixtures. In their case, however, the new coloration due to the mixture is present only in the cold condition. If it were known how such colors, different from those of the constituents, originated, a new field for the search for coloring materials might be opened.

IX. MISCELLANEOUS DATA.

Effect of Variation in Weight on Mantle Temperature.

As has been mentioned before, it was not feasible to determine for each mantle material investigated the weight to give the best

compromise between luminous efficiency and mechanical properties. It is therefore of considerable importance to know how the temperature of a representative mantle varies with the weight. For this purpose a series of pure thoria mantles was made up, varying from 0.65 to 1.4 units in weight, and temperature measurements were made on them by the thermocouple method.

These measurements showed a nearly rectilinear relation between weight and temperature over this range, from 1930° for the lightest to 1860° for the heaviest mantle. Taking this as representative, it is evident that no important alteration in the relative standing of the various "bases" could be brought about by practical variations in their weight in mantle form. The nearest "base" to thoria—namely, magnesia (1840°)—might by a very considerable reduction in weight approximate the ordinary weight thoria mantle. It is, however, so inferior to the latter in mechanical strength and durability as to make this probability of small promise.

X. GENERAL DISCUSSION OF MANTLE EFFICIENCY AND ITS LIMITATIONS.

1. *Limitation to Radiant Luminous Efficiency Set by Attainable Temperature.*

Of the two variables at our disposal in selective temperature radiation—temperature, and the composition of the radiator—the first meets with a definite limitation in the case of the gas mantle in the temperature of the flame used for heating. With ordinary illuminating gas under the pressures common in commercial practice the attainable flame temperature is in the neighborhood of 2100° K. From the standpoint of light-production, this temperature is excessively low, being approximately that of the carbon filament, and lying some hundreds of degrees lower than the operating temperatures of the tungsten filament incandescent lamps. The radiant luminous efficiency of the black body at 2100° K. is about ½ per cent.; consequently the task of attaining an efficiency of only a few per cent. calls for a radiator of most pronouncedly selective character, even assuming that the flame temperature were taken by the radiator, which would be the case only if the latter's emissive power were of the order of 1 per cent. or less. With higher emissive powers the temperature assumed is, as has been seen, reduced, and this means a rapid loss of efficiency.

In order to learn approximately what improvement in effi-

ciency might be expected if the regular mantle could be operated at higher temperature, a series of measurements were made on a mantle heated in a flame fed with various amounts of oxygen. Radiant luminous efficiencies were measured against optically read temperatures. The results are plotted in Fig. 13 (II), from which it appears that the efficiency of the radiation increases by about three times as the temperature rises from 1900° (regular mantle temperature) to 2100°. This rate of increase is approximately that of the black body, and if continued at the same rate would mean the attainment of an efficiency some twenty times greater at 3000°, which is somewhere near the temperature of operation of the nitrogen-filled tungsten lamp. Actually the rate of increase of efficiency could be made more rapid, because a progressively larger amount of ceria could be added to advantage at the higher temperatures. Such an efficiency (9 per cent.) is far above any present incandescent illuminant, and shows clearly that the actual low efficiency of the mantle is not so much the fault of its radiating properties as of the temperature to which it is limited. (This speculation says nothing with regard to the effect on the various heat losses were such a temperature attained, which will be treated separately below.)

2. *Limitations to Radiant Luminous Efficiency Set by the Temperatures Which the Mantle Materials will Stand.*

Aside from the question of means for attaining higher efficiency by higher temperatures, a vital matter to be considered is the effect of higher temperatures on the mantle materials.

The melting-point of thoria is given by Ruff [12] as 2440° C. (2713° K.), and that of ceria as 1950° C. (2223° K.). The former temperature is, of course, the upper limit of operation of a thoria base mantle, the lower that of a mantle containing ceria. There is good evidence, however, that ceria begins to volatilize at the ordinary mantle operating temperature. White and Mueller [13] have made observations on various mantles before and after burning for extended periods, and demonstrated the loss of ceria both by the variation in efficiency and by analysis. The increasing rate of candle-power depreciation with high-pressure burners is in line with their findings.

Closely allied to this question of melting and volatilization points is that of the physical strength of the mantle. This must

be sufficient to give a useful life when subject to the average shocks of operation. The lighter the structure can be the higher the temperature it can take, as shown by the data on the thoria mantles of various weights, and the exact compromise between durability and efficiency must be determined from practical considerations.

3. *Radiant Luminous Efficiencies Theoretically Attainable with the Bunsen Flame and Thoria Base.*

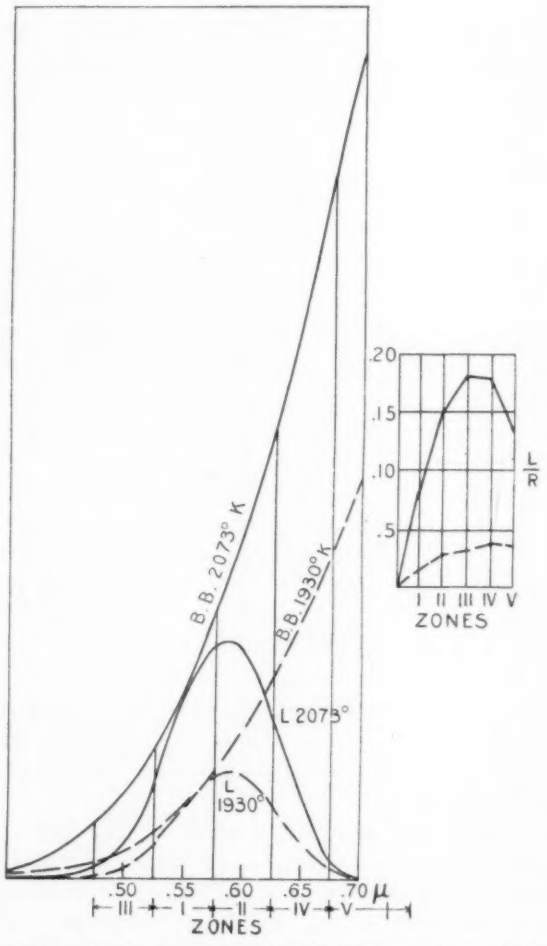
The attainment of the maximum possible efficiency, and the high efficiencies which have been suggested as possible from the materials of the present Welsbach mantle, would demand a freedom in the choice of radiating materials on the one hand, or of temperatures on the other, which we are far from realizing. It therefore becomes of interest, having established the limits of temperature at our disposal, and the characteristics of the radiator of lowest emissive power at our disposal (thoria), to investigate what efficiencies should be theoretically possible under the limitations thus set. All of the information necessary for such calculations is now at our disposal.

Let us first consider the possibilities of the Bunsen flame as a "base" for carrying a layer of selective radiator. We shall assume that its temperature is 1800° C. (2073° K.), and for its total emissive power we shall take the values resulting from using the actual radiation as measured in this investigation, which is 0.0116. We may further assume, without material inaccuracy, that the flame gives no appreciable light.

In Fig. 35 is plotted (BB) the spectral emission curve of the black body at 2073° K. for the visible region, and (L) the luminosity curve for the same black body. The ratio of the area of this luminosity curve to the area of the complete emission curve is the luminous efficiency of the black-body radiation at this temperature, and has the value 0.0032. Now, with this piece of information at our disposal, it is at once possible to calculate the contribution to the total radiation and to the total light of any emissive power in any part of the visible spectrum. The process is shown graphically in the figure. We first assume that to the colorless Bunsen flame is added a narrow zone of unit emissive power at the wave-length of maximum luminous efficiency. For ease of calculation we may take this band fairly wide, say 0.05 μ.

Call this zone I. The addition to the total radiant energy is the area of this zone lying under curve BB; the addition to the luminous energy is the area lying under the curve L, each, of

FIG. 35.



Calculation of possible radiant luminous efficiencies using the Bunsen flame (full lines) and thoria (dashed lines) as bases.

course, being expressed in the unit fixed by the value of the area of curve L, above derived. Thus for zone I the area under BB, in terms of the area L = 0.0032, is 0.00175; the area under L is

0.00107. From this we get that the radiant luminous efficiency of the Bunsen flame + zone I of unit emissive power—*i.e.*, the ratio of the luminous to the total energy—is

$$\frac{.00107}{.0116+.00175}=.08$$

Adding by this same process successive zones on each side of the original one, of lower and lower luminous efficiency, we obtain for the luminous efficiencies as follows:

Bunsen flame + Zone I	0.084
Bunsen flame + Zone I + Zone II	.159
Bunsen flame + Zone I + Zone II + Zone III	.169
Bunsen flame + Zone I + Zone II + Zone III + Zone IV	.166

Beyond this point the added zones lying largely or wholly in the infra-red or ultra-violet contribute to the total energy and not to the luminous energy, and reduce the efficiency, which goes through a maximum at approximately 17 per cent.

This efficiency is subject to a certain reduction, due to the fact that the total radiation is approximately doubled by this additional emissive power, and such an increase, as we have seen, reduces the temperature of the radiator. From the experimental curve of Fig. 10 (I) we may estimate that the temperature reduction would be to about 2000° K. Assuming that the resultant drop in efficiency is approximately that which a black body would suffer by such a lowering of temperature, we make a deduction of 20 per cent., leaving an efficiency of about 13 per cent.

It is obvious that this calculation, to be highly accurate, should be carried through by quite small steps, and the change of temperature introduced at each step, but the figure obtained by the rougher method here used is substantially accurate—certainly sufficiently so for our present purposes.

It next becomes of interest to study by the same method to what efficiency we are restricted if no better base than thoria is found, assuming the possibility of adding a colorant of the ideal character represented by the zone just assumed added to the Bunsen flame. We may take, for the temperature assumed in the flame by the thoria base, 1930° K.; for its emissive power, 0.043; for the efficiency of the black body at this temperature, 0.0018, the light given by the thoria being small enough to be negligible. Proceeding as before, we obtain for

Thoria base + Zone I	0.0135
Thoria base + Zone I + Zone II	.029
Thoria base + Zone I + Zone II + Zone III	.0296
Thoria base + Zone I + Zone II + Zone III + Zone IV	.034
Thoria base + Zone I + Zone II + Zone III + Zone IV + Zone V	.032

As before, this efficiency must be corrected, owing to the temperature reduction caused by the radiation increasing from 0.043 to about 0.05 that of the black body at 1930°. Judging by the regular thoria-ceria mantle, this reduction would probably not amount to more than 30°, resulting in about 15 per cent. loss of efficiency, leaving a net possible radiant luminous efficiency of 0.029. This is approximately *three times* the radiant luminous efficiency given by ceria as a colorant (making the comparison with the efficiency attained in the brightest part of the mantle, where alone the assumed temperature applies).

A point of considerable interest which comes out of this study is that the maximum efficiencies thus calculated are obtained with very nearly the complete visible spectrum endowed with full emissive power. If the base were absolutely transparent and non-emissive, the most efficient coloring medium would be one with emissive power restricted to the middle, most efficient part of the spectrum; that is, one giving a yellow-green light. With the presence, however, of invisible emission in the base, a considerable quantity of visible radiation may be added, even though not all of good efficiency, before the increment to the total radiation, which is the denominator of the efficiency fraction, begins to increase at the same rate as the visible part.

It appears, from this calculation, that by using the present thoria base, without any increase of flame temperature, a very substantial increase of luminous efficiency could be obtained, provided a coloring material of the proper characteristics were available. The desired colorant would differ from ceria in two respects: First, it would add nothing to the radiation in the long wave-region near 2 μ; and, second, the absorption band which is responsible for the visible emission would be sharply defined on the red side, more like the bands of neodymium than the gentle slope of the ceria band. Of these two differences, the second would be of the greater importance, for, with everything else left the same in the ordinary mantle, any increase in the emissive

power near 0.6 μ (which is only about 20 per cent.) at the expense of the emissive power at the red end of the visible spectrum and near infra-red would appear directly in the efficiency.

4. *Heat Losses in the Burner and Mantle-lighting Unit. Hydraulic Analogy.*

Attention has been directed chiefly in this investigation to the study of the radiating properties of various materials, and the information desired has been the luminous efficiency of their radiation. The methods of study employed give, however, information which is of interest and value on the sources of inefficiency of the whole mantle-burner combination.

Thus, as has been pointed out elsewhere, the ratio of the total luminous efficiency to the radiant luminous efficiency gives the radiational efficiency, or efficiency of transformation of the applied energy into the radiant form. The total luminous efficiency obtained from the lumens per watt rating and the mechanical equivalent of light is 0.0019. Dividing this by the radiant luminous efficiency (as obtained in this work for the horizontal direction) gives 0.44, or an efficiency of transformation of applied energy into radiant energy of less than one-half. Using an earlier figure, obtained by Karrer for the mantle with a glass chimney—namely, 0.019—this efficiency drops to about one-sixth. Without radiant luminous efficiency figures for the whole radiation (instead of in one direction only) it is not possible to calculate the radiational efficiency accurately in this way, but it is clearly quite low. A more accurate method of calculating the losses, which are obviously those due to convection and conduction, is obtained by making a heat balance for the mantle and burner. If we assume that the products of combustion leave the mantle at the temperature of the latter, we can, by knowing the specific heat of these products and their amount, calculate the amount of energy carried away by them, thus getting the convection losses, which are probably the greater portion of the losses.

The result of carrying through these calculations for a mantle at several different temperatures is shown in Fig. 9 (III). A gas of 630 B.t.u. per cubic feet was assumed, and the specific heats in B.t.u. per cubic foot of gas consumed per degree centigrade at various temperatures were plotted from standard tables. The cal-

culation then consisted in comparing the ratio of this specific heat to the initial (630).

It appears, from this figure, that the energy loss by convection is, for the ordinary mantle at about 1900° K., close to 75 per cent. Furthermore, this loss is different at different temperatures, decreasing with lower temperatures, being only about 45 per cent. for the ceria mantle temperature (1350°). Hence any increase in efficiency sought by increasing mantle temperature is, other conditions being unchanged, offset in large degree by the increase in convection losses.

The accuracy of this curve (and the validity of the assumption that the convection losses are practically the total losses) is indicated by the experimental points (circles) obtained by Kingsbury during an earlier study of radiant heaters by a calorimetric method. This decrease of radiation with increasing temperature is in entire accord with the relationship between temperature and total radiation found in connection with the measurement of temperature by total radiation.

It is evident, from a study of the figures used in the calculation, that a large part of the convection loss is due to the volume of inert nitrogen carried through the flame. The effect of this is shown graphically by the additional dashed curve of Fig. 9 (III) calculated for the condition that combustion takes place in oxygen instead of air. The losses are less than half as great, but increase with increasing temperature as with air.

The whole behavior of the burner and mantle may be represented by an extension of the hydraulic analogy suggested by Wood [14] for the mantle alone.

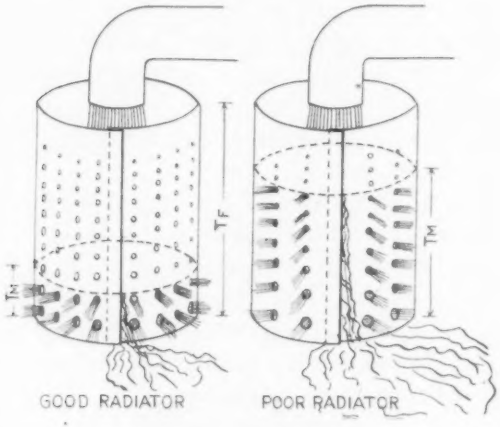
We can imagine the mantle to be represented by a vertical cylindrical tank into which water is flowing at a constant rate from a tap (Fig. 36). The wall of the tank is to be imagined as perforated by holes of various sizes. The water which squirts out through these holes is the radiation, and the various sizes of holes represent various wave-lengths. If the smaller holes are more numerous at the top of the tank, then the higher the water rises the more will squirt out through the smaller holes, thus copying the behavior of a material radiator, water *height* being taken to represent *temperature*.

If now we take a tank containing many holes, the water will

not rise very high, and, conversely, in one with only very few holes the water will rise higher, thus copying the behavior of mantles of high and low emissive powers, in so far as their temperature characteristics are concerned. If the holes are all made small, only squirts of small size will be present, and the water will rise higher than if holes of all sizes are present, thus copying the characteristics of a selective radiator like the mantle.

In order for this tank to represent the behavior of the mantle with respect to the amount of radiation, it is only necessary to imagine a vertical seam of the tank to have been left unsoldered,

FIG. 36.



Hydraulic analogy of mantle and burner: T_m = Mantle temperature. T_f = Flame temperature.

so that a bad leak is present, to represent the convection and conduction losses. The higher the water rises, as when the radiating holes are made few in number, the more is lost through the leaky seam, and so the less is " radiated " through the holes. Obviously, with a constant rate of supply the advantage of increased " temperature " is being more and more offset by the leakage.

To go back to the actual mantle, it appears that by eliminating the convection loss the temperature attainable and its availability for producing radiation would be much increased. This is what occurs when the mantle is heated *in vacuo*. If, for instance, a ceria mantle and a thoria mantle are receiving energy at the same rate from the cathode stream, the ceria mantle saves through

elimination of convection losses and diverts to radiation about 80 per cent. more than it does of the same energy supplied by the flame; the thoria mantle, on the other hand, retains for radiating purposes *four times* what it does when heated by the flame. The effect of this on the temperature attained could be found only by studying the relation between total radiation and temperature in the mantle materials. A black body radiating n times the energy of the same body at the temperature T must have the temperature

$$\sqrt[4]{nT}$$

For 80 and 400 per cent. the increase in temperature would be approximately 15 and 40 per cent. respectively. The latter increase on 1900° would correspond to an enormously greater increase in luminous radiation than the former on the lower temperature of 1350°.

It has already been shown how the failure of ceria to color the mantle, in the cathode discharge, explains the lack of superiority of the ceria-thoria mixture over pure thoria under those conditions. The large reduction in convection losses in the vacuum tube explains why pure thoria should be so overwhelmingly superior to pure ceria in the cathode discharge, although nearly alike in the flame, thus giving a complete explanation of the differences in behavior, which have been a long-standing puzzle.

5. *The Total Luminous Efficiency Attainable with the Bunsen Flame as the Source of Heat.*

With the information on convection losses just obtained, it is of interest to consider again the limitations of the Bunsen flame as a source of heat for producing light. Thus far we have considered merely the *radiant* luminous efficiency attainable by adding an ideal colorant to the flame. This has been found to be approximately 13 per cent. with air, accompanying a temperature of about 2000° K. In order to get the *total* luminous efficiency of the burner and mantle, this figure must be multiplied by the radiational efficiency for 2000° K. as given in Fig. 9 (III); namely, 20 per cent. The total luminous efficiency thus derived is 2.6 per cent.

This figure represents the maximum possible efficiency attainable by heating a mantle in the customary manner by means of a

Bunsen flame. While over thirteen times that of the present mantle gas light (0.0019), it is yet very low as an absolute efficiency. It is, in fact, below the value already attained by the nitrogen-filled tungsten lamp (0.032). It must be remembered, however, in this connection, that the process of obtaining the stored energy from coal by the production of gas is much more efficient than is the process, employing boiler and engine, used for transforming the energy to electrical form. As a consequence the efficiency measured from the coal pile is not greatly different for the two kinds of light.

XI. GENERAL SUMMARY.

The investigation here described, in so far as it deals with the radiating characteristics of the incandescent mantle, constitutes chiefly an extension of the work of Rubens on the thoria-ceria mixtures, to a large family of such combinations. It exhibits the Welsbach mantle of commerce simply as one of a group of possible combinations of radiating materials, behaving according to the same general laws, but remarkable among them for the degree to which the characteristics of selective radiation are exhibited.

A more detailed study has been made than any heretofore on the behavior under various conditions of the absorption bands to which the enhanced visible radiation of the more efficient mantles are due. While no *explanation* has been found for the occurrence of the visible absorption bands of ceria and other materials—a question to be solved only by an intimate knowledge of the structure of matter—the information learned as to the conditions under which they appear and disappear has made possible a rather complete explanation of some long-standing enigmas, notably that of the different behavior of the mantle in flame and cathode-discharge heating.

Another line of investigation has here been taken up apparently for the first time in any detail; namely, that of the energy relations holding with flame heating of radiating materials. As a result of the study it has been possible to fix with some definiteness the possible attainable efficiencies of gas-light production by present methods. These, while low, are still many times any now reached.

NOTES.

[1] Rubens, *Annalen der Physik*, **20**, 3, p. 593 (1906).

[2] For instance, Wood's "Physical Optics" or Burgess and Le Chatellier's "High Temperature Measurement." An excellent review of mantle theories is given by Fulweiler, *Trans. I. E. S.*, iv, p. 65, 1909.

[3] See Ives, "The Units and Nomenclature of Radiation and Illumination," *Astrophysical Journal*, January, 1917, p. 39.

[4] Ives, "Establishment of Photometry on a Physical Basis," JOURNAL OF THE FRANKLIN INSTITUTE, October, 1915, p. 409.

[5] Ives and Kingsbury, "Physical Photometry with a Thermopile Artificial Eye," *Physical Review*, November, 1915, p. 319.

[6] White and Travers, *Jour. Soc. Chem. Ind.*, **15** (1902), p. 1012.

[7] Langmuir, *Physical Review*, xxxiv, p. 401 (1912).

[8] Féry, *Ann. de Chem. et de Phys.*, **27** (1902), p. 433.

[9] See Levy, "The Rare Earths," p. 177.

[10] Campbell-Swinton, *Proc. Roy. Soc.*, **65** (1899), p. 115.

[11] Killing, *Journ. für Gasbel.*, **50**, p. 90.

[12] Ruff, *Zeits. anag. Chem.*, **82**, p. 373 (1913).

[13] White and Mueller, *Jour. Gas Lighting*, **83** (1903), p. 504.

[14] Wood, *Physical Review*, xxiv, p. 437 (1907).

Manufacturing Destroyers. H. O'HIGGINS. (*The Official Facts.* Committee on Public Information, Washington, D. C., September, 1918).—It formerly took two years to build a fast destroyer. One has just been built in a little more than two months. These craft, costing two million dollars each, have the engine power of the old battleship *Maine* and the speed of a motor boat. Experience has shown that they are the most effective weapon against the submarine. At the outbreak of the war we succeeded in completing one in eight months instead of two years. Then, with the speeding up of production, another was completed in six months. Now, in the Mare Island Navy Yard, the destroyer *Ward* has been launched 77½ days after its keel was laid, and it has been completed in seventy days.

There is no magic in this enormously increased rate of production; we are now not building destroyers, we are manufacturing them. The process by which the *Ward* was manufactured is a machine process, by which we can produce at the same rate, as many destroyers as we need. The steel parts are prepared, in various plants, all over the country, in accordance with standardized plans. These parts are assembled in navy yards, put together at the docks, swung into position and riveted in place by a force of men working night and day. In other words standardized destroyers are being turned out as standard automobiles are turned out, in quantity production. The Navy Department reports that one flotilla of these destroyers, having steamed a million miles on patrol, has protected 86 convoys and 717 single vessels, and fought 81 submarines without any loss to the destroyers or to the vessels which they escorted.

The Remelting of Aluminum Pig in the Electric Furnace. D. H. MILLER. (*Chemical and Metallurgical Engineering,* vol. 19, No. 5, September 1, 1918.)—About one-half of the total amount of the aluminum used in this country is manufactured in the plant of the United States Aluminum Company at Massena, New York. Here the pig metal as it comes from the reduction plant is remelted for the purpose of casting it into ingots or rolling billets. A number of aluminum alloys are also made and the metal heat treated in the electric furnace after having been rolled down into rods or conductors. The object of this remelting is to cleanse the metal by removing in this manner the slag and scum contained from the reduction process. After the remelting there is a distinct and marked difference in its appearance, as it loses its dull finish and is much brighter. Since a very great quantitiy of aluminum is handled at this plant, even the smallest saving in metal loss is important and soon manifests itself in the aggregate savings. Hence, with the idea of experimenting with just what could be done in the way of effecting savings as well as in improving the quality of the metal, the United States Aluminum Company installed electric furnaces both for remelting and heat-treating the metal.

The furnace selected for remelting is a stationary resistance type and has a bowl-shaped hearth capable of holding three to four tons of molten metal. It is rated at 500 KW. and designed for single-phase 25-cycle operation. When running continuously the furnace can melt one ton per hour, which is topped into graphite crucibles holding about 125 pounds. The daily output of the furnace is twenty tons. The advantages which are secured by the use of the electric furnace are summed up by Mr. H. M. Hall, Superintendent, as follows: (1) The electric furnace replaced an oil furnace burning crude petroleum oil which produced large losses, particularly in the case of alloys containing volatile constituents, such as zinc. (2) The electric furnace gives much more uniform mixtures, with much less loss. (3) The cost of electric power compares very favorably with the increased cost of fuel oil which was becoming prohibitive. (4) Savings are effected by the use of the electric furnace in that the metal losses are less and the thermal efficiency greatly increased. (5) Where coal-fired furnaces are used, there is a saving of one or two men in favor of the electric furnace. (6) There is also a saving in space required for a given weight of metal melted in favor of the electric over the coal-fired furnace. (7) The electric furnace is much cleaner and cooler to operate than is the case with an externally-fired fuel furnace. It is evident that while improved quality of product was the end sought, economy of operation resulted from the use of electricity as its heating medium.

A SURFACE HAVING ONLY A SINGLE SIDE.*

[ADDENDUM.]

BY

CARL HERING, D.Sc.,

Member of the Institute.

In the August, 1918, issue of this JOURNAL, page 233, the writer described an odd form of surface which differs from the

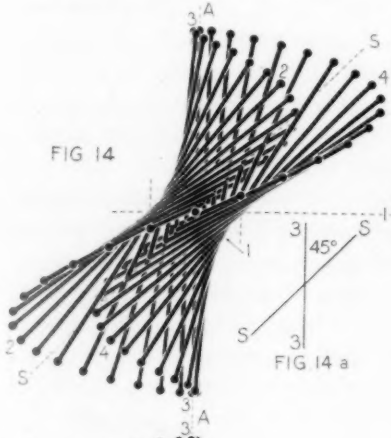


FIG 14 a

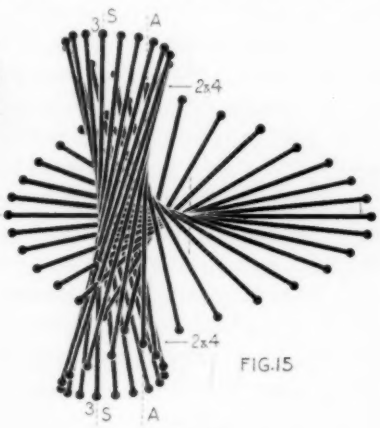


FIG.15

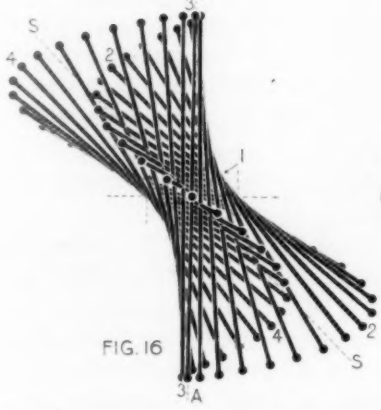


FIG. 16

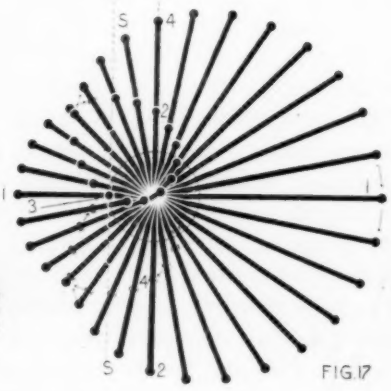


FIG.17

usual surfaces in having only one side, and in a mathematical sense must therefore be considered non-polar or unipolar.

Since then the writer has made a further investigation of the

* Communicated by the Author.

algebraic equation of this surface which was added to the former article just before going to press, and has endeavored to give a better conception of this surface by means of some additional drawings.

It is difficult to show this peculiarly curved surface by means of flat drawings other than stereoscopic views. Nor can it be shown by a shaded drawing as though made of cardboard, as it is in a sense hollow, or more correctly, doubly hollow; it should be shown as though transparent. The accompanying diagrams, Figs. 14, 15, 16 and 17, were therefore drawn accurately to scale showing it in the form of a succession of lines or rods representing its rectilinear elements in their successive positions in developing this surface. This gives the desired effect of transparency, and by making use of the conventional shading and the knobs at the ends, and by showing the self-intersection, the desired stereoscopic effect is at least approached.

The two slanting, neighboring, trumpet-shaped holes or passages through it, which in a sense make it doubly hollow, unfortunately cannot be shown as openings in any of these drawings, each of which is taken perpendicularly to some one of the four cardinal positions of the elements. These passages can be seen best in Fig. 16 when one conceives that the row of knobs through the middle represents a series of elements forming a partition which divides the tubular interior into two oblique passages.

In all of these figures the four cardinal positions, 1, 2, 3 and 4 of Fig. 1, are marked with their respective numbers. *AA* represents the central axis and *SS* the line along which this surface interests itself. The lengths of the elements were made equal to four times the diameter of the circular directrix, which is shown in Fig. 17; beyond that distance there is nothing more of interest.

Fig. 14, corresponding to the former Fig. 4, is a view in line with position 1 of Fig. 1, taken from the right, while Fig. 16, corresponding to the former Fig. 6, is the same taken from the left. Fig. 15, corresponding to the former Fig. 5, is taken in line with the plane of 2 and 4 (which two positions coincide in this view), hence is a view of Fig. 14 from the left, or of Fig. 16 from the right; it shows the two trumpet-shaped and the two fan-shaped parts. Fig. 17 is the top view of Fig. 15 in line with the axis; each of the positions in this view necessarily represents two diametrically opposite elements which therefore

partially overlap; the knobs indicate the ends of these superimposed elements.

From the group of rectilinear cross sections, Figs. 8 to 13 in the former article, one was overlooked; it is the vertical section through the position 3 and the line of intersection *SS*, hence perpendicular to position 1; it is a cross section of Fig. 14 parallel to the plane of the paper and slightly to the rear of it; it is shown on a reduced scale in the supplementary Fig. 14a. It is one of the simplest of these cross sections.

In the algebraic equation given in the former article there is an error in two of the signs; the sign before ryz should be – and not +, while the one after yz should be + and not –. Dr. C. P. Steinmetz subsequently reduced it to the following form:

$$y(y+z)^2-y(r+x)^2+2x(y+z)(r+x)=O$$

The writer has reduced it to the following, which he believes to be its simplest form:

$$y(x^2+y^2+z^2-r^2)+2z(x^2+y^2+rx)=O$$

In these the geometric centre of the surface is at the origin of the system of coördinates, and the circle of radius r is in the plane of X and Y; hence the axis A in the figures is the axis of coördinates Z; position 1 lies in the positive direction of X. Both of the angular motions are assumed to be clockwise, as shown in Fig. 1; when one is clockwise and the other anti-clockwise the only change in the latter equation is that the sign before the $2z$ is negative.

Inserting in this equation $x=-r$ gives $y=-z$, which proves mathematically that the self-intersection of this curved surface is a right line lying in a plane perpendicular to position 1 and through position 3; and that it makes an angle of 45° with the horizontal or vertical, as shown in Fig. 14a. The result $y=-z$ also shows that it lies in the quadrants $+z$, $-y$, and $+y$, $-z$, all of which will be seen to be confirmed in the drawings by the line *SS*, and was first noticed by the writer in the models.

In all the above the clockwise direction was assumed for both of the angular motions, as described in connection with Fig. 1; if both directions are anti-clockwise the results will, of course, be the same as before; but if one is clockwise and the other anti-clockwise this line of self-intersection *SS* will lie in the other pair of quadrants, that is, will be at right angles to its position in Fig. 14a, and its equation will then be $y=z$, as the

sign before $2z$ in the above equation is then $-$ instead of $+$. These two forms of this surface bear the same relations to each other as a right- and a left-handed screw thread.

As an additional proof of this curious rectiliear self-intersection, the writer started with the assumption that it was this 45° right line and developed the equation of a surface generated by the movement of a right line so that it always touches: *(a)* a circle, *(b)* the axis of the circle, and *(c)* a right line making an angle of 45° with the plane of the circle and lying in a plane tangential to the circle. The equation thus obtained was identical with the second one given above. The same surface may therefore be correctly defined in either way.

The above equations were furthermore tested by deducing from them the cross sections, Figs. 8, 9 and 10. Making $z=0$ gives the equation of the section Fig. 8. Making $y=0$ gives the equation of the section Fig. 9. Making $x=0$ gives the equation of the section Fig. 10.

Using polar coördinates in the plane of the circular directrix (the plane of X and Y, see Fig. 17), and letting a be the angle of the projection of an element on that plane measured clockwise, R the radius vector of the projection of any point of that element, and z as before the vertical distance of that point above or below this plane, then the equation at the end of the former article (after correcting the signs) reduces to the much simpler forms:

$$z=(r-R)\tan\tfrac{1}{2}a$$

$$z=(R-r)\cot a-(R-r)\operatorname{cosecant} a$$

from which the value of z of that point may be easily determined. The first expression is the more convenient for arithmetical calculations, care being given to the signs and to the directions of rotation. The second expression gives a completely graphical and very simple solution, for by striking an arc through the point in question with a radius of $R-r$, using as a centre the point of intersection of the radius vector R with the circular directrix, and drawing the necessary cotangent, the quantities $(R-r)\ cot\ a$ and $(R-r)\ cosecant\ a$, are given graphically, and as the lines representing them intersect, their difference, namely the desired value of z, is readily measured off. "Descriptive geometry," so-called, provides another completely graphical solution.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A PORTABLE APPARATUS FOR DEVELOPING MOTION-PICTURE FILM AT NORMAL AND AT HIGH TEMPERATURES.[1]

By J. I. Crabtree.

[ABSTRACT.]

By an application of the apron method of developing films as adopted in the Kodak Film Tank outfit, a portable and compact apparatus has been devised for the development of motion picture film, while by applying the method of developing at high temperatures as described in Communication No. 62 (B. J. 1917, p. 555), it is possible to develop motion picture film up to temperatures as high as 95° F. In view of this and the portability of the apparatus it is hoped that the method will be of particular value to explorers traveling in tropical countries who must develop their film as soon as possible after exposure and under existing conditions.

The apparatus consists of a celluloid apron somewhat wider than the width of motion picture film, and a suitable reeling apparatus and developing tanks, the film being wound onto the apron, developed, fixed and washed in the apron, and finally dried by transferring to a collapsible frame rack in the usual way.

The formula for the T_6 developer recommended is as follows:

	Avoirdupois	Metric
Paraminophenol hydrochloride or Kodelon	105 grains	7 grams
Sodium Sulphite (desiccated)	1 oz. 300 grains	50 grams
Sodium Carbonate (desiccated)	1 oz. 300 grains	50 grams
Water to	32 ozs.	1000 c.c.

The time of development with this developer is 1½ minutes at 95° F., but if this is too short for convenience in working, the time may be extended to three minutes by adding 10 per cent. sodium sulphate to the developer before use.

* Communicated by the Director.

[1] Communication No. 74 from the Research Laboratory of the Eastman Kodak Company, published in *Mot. Pic. News*, 1918, p. 1582 and p. 1742.

After developing, rinse for a few seconds and fix in the following chrome alum bath at temperatures up to 85° F.

	Avoirdupois	Metric
Hypo	7 ozs.	200 grams
Sodium Sulphite (desiccated)	1 oz. 175 grains	40 grams
Chrome Alum	2 ozs. 350 grains	80 grams
Acetic Acid (28 per cent)	150 minims	10 c.c.
Water to	32 ozs.	1 liter

Dissolve the sulphate and chrome alum together and add to the hypo solution, finally adding the acetic acid.

At temperatures up to 95° F. the following formalin bath should be employed:

	Avoirdupois	Metric
Hypo	9 ozs.	250 grams
Sodium Sulphite (desiccated)	1 oz. 350 grains	50 grams
Formalin (formaldehyde 40 per cent)	4¼ ozs.	125 c.c.
Water to	32 ozs.	1 liter

First dissolve the hypo, then the sulphite, and finally add the formalin.

When developing at high temperatures it is very necessary to maintain the temperature of the developer, fixing bath, and wash water the same, otherwise if the film is transferred from a hot to a cold solution, or *vice versa*, reticulation of the gelatine coating is liable to occur.

By a slight modification the apparatus could be made suitable for daylight developing, though this would necessitate the carrying of a collapsible box to fit around the reeling apparatus.

The author is indebted to Mr. S. Tulpan for his valuable assistance in the carrying out of the various experiments.

THE EFFECT OF SIZE OF STIMULUS ON THE CONTRAST SENSIBILITY OF THE RETINA.[2]

By Prentice Reeves.

[ABSTRACT.]

THE experiments were made with the visual sensitometer devised by Nutting and are of the nature of a continuation of the work of Nutting and Blanchard on the sensitometry of the eye.

[2] Communication No. 70 from the Research Laboratory of the Eastman Kodak Company, published in *J. Optical Society of America*, 1917, p. 148.

Five contrasts and six stimulating areas or test spots were chosen. The contrasts were 0, 0.39, 0.67, 0.87 and 0.97. The sizes of the illuminated test squares were 2, 5, 7, 25 and 30 mm. Neutral film of the necessary opacity placed over half of the square furnished the contrasting areas. For each size of square and for each contrast, the times necessary to see the illuminated area for a number of field brightnesses were noted, from which a double series of curves connecting field brightnesses with time of appearance are obtained.

The Fechner fraction, dB/B, is next obtained and plotted as a function of field brightness. A family of such curves is found by varying the adaptation time from 0 to 60 seconds.

Lastly, a simple application of these results is made to the problem of aeroplane detection. The writer concludes that if an aeroplane of 40 feet spread, with a contrast against the sky of 0.97 is just visible at 467 feet elevation, then its contrast would have to be 0.65 at an elevation of 7000 feet for it to remain visible. At 1700 feet its contrast with the same limitations should be 0.87.

Thread Rolling. F. D. JONES. (*Machinery*, vol. 24, No. 8, p. 690, April, 1918.)—The rolling process of forming screw threads may be defined as an impression or displacement method, since the thread grooves are not cut by an edged tool, but are formed by means of a die or roll having threads or ridges which are forced into the metal and, by displacing it, produce a thread corresponding to the required shape and pitch. The plain blanks upon which threads are to be rolled are somewhat smaller in diameter than the finished thread, because when a thread is rolled a certain amount of metal is displaced and is forced up above the original surface of the blank, thus producing a screw thread which is larger in diameter than the original blank. The increase in diameter is approximately equal to the depth of one thread. No material whatever is removed by the rolling process, the metal from the depression formed by the die simply being forced up on each side.

Screw threads may be rolled (1) by using a circular disk or roll having a threaded periphery, or (2) by rolling the blank between dies which may be either flat or circular in form. The circular roll is employed when screw threads are rolled on automatic screw machines or turret lathes, and the dies referred to are used when thread rolling is done by means of machines designed exclusively for this work. Thread rolling is done in automatic screw machines when a thread is required behind a shoulder or other intervening part, which makes it impossible to cut it by using a regular thread-cutting die. The advantage of rolling the thread in

such cases is that a second operation is avoided. The important commercial application of the thread-rolling process is found in the shops and factories using machines designed especially for this work. These machines are extensively employed in certain lines of manufacture for threading such parts as bolts, screws, studs, rods, etc., especially where such threaded parts are required in large quantities. Screw threads that are within the range of the rolling process may be produced more rapidly by this method than in any other way, which accounts for the use of thread-rolling machines in connection with bolt and screw manufacture and wherever thousands of duplicate threaded parts are required.

Waterproofing Drawings and Tracings Without Crimping. J. S. CARPENTER. (*Engineering News-Record*, vol. 81, No. 13, p. 597, September 26, 1918).—Waterproofing of drawings and tracings so that they can be used in wet places, as in mines, is done by the use of a preparation composed of rubber and benzol. The solution in less dilute form also makes a paste which may be used to join tracings and maps without the crimping of the joint that commonly occurs when water pastes are used. The pure gum rubber which is required for this waterproof paste can be bought at wholesale drug houses; the benzol can be obtained at most paint stores. The benzol-rubber solution will keep in any climate and under any conditions. As benzol is inflammable, it should be kept in a safe place in a covered jar. If proper precautions are taken in its use, however, it is no more dangerous than kerosene.

A convenient quantity of the solution may be made by adding a piece of rubber about 4 inches square to a half pint of benzol in a quart jar. The rubber will soon swell to three or four times its former bulk and will be ready for use in 24 hours. To prepare for use, pour about half the above quantity in another jar for thinning down. If drawings are to be coated, use a rather thin solution that will spread well under a brush. The drawing should be coated on both sides. For use as an adhesive, the solution should be fairly stiff, so that if it is desirable afterward to separate the joined parts, it can be done more readily than if a thin paste is used. There are cases where large tracings and blueprints must be made up of smaller sections, and for this work the paste is invaluable, as the joints will not be crimped out of shape and alignment. An additional use for the preparation was suggested when some of this solution was spilled accidentally on a dirty drawing. When the benzol was mopped up with a rag, the rubber was rolled up into a ball and the drawing was effectually cleaned by the operation.

Rubber bands instead of pure gum were tried, but it was found that they would not dissolve; they merely swelled up to many times their former size. Formaldehyde also was tried as a solvent, but its objectionable odor and certain other characteristics have proved it to be undesirable. When diluted as above directed the pure gum paste will not be costly.

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Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., 1st Lieut.	Air Service, U. S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France

Name and rank	Branch of service	Location
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Private	437th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Washington
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington

Name and rank	Branch of service	Location
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U. S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.

Name	Appointment	Location
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Wahington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia

Name	Appointment	Location
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William F.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 2, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 2, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2724.—Rolin Patent Adjustable and Interchangeable Grate.

GEO. A. HOADLEY,
Acting Secretary.

LIBRARY NOTES.

PURCHASES.

FERRY, E. S.—Practical Pyrometry; the Theory, Calibration and use of Instruments for the Measurement of High Temperatures. 1917.

FRANKE, G.—Handbook of Briquetting. Vol. 2. 1918.
HAZEN, A.—Meter Rates for Water Works. 1918.
LAKE, S.—The Submarine in War and Peace; Its Developments and Its Possibilities. 1918.
MACELWEE, R. S.—Ports and Terminal Facilities. 1918.
North Carolina Geological Survey, Vol. 1, 1905. Vol. 2, 1907.
SIBLEY, R., and DELANEY, C. H.—Elements of Fuel Oil and Steam Engineering. 1918.
West Virginia Geological Survey.—County Reports and Maps. Barbour and Upshur Counties. 2 Vols. 1918.

BOOK NOTICES.

THE ZINC INDUSTRY: By Ernest A. Smith. London. Longmans, Green and Company, 1918, 211 pages, contents, bibliography and index, illustrations. 8vo. Price, $3.50.

This is one of the excellent series of monographs on industrial chemistry, several of which have already been noted in this JOURNAL. The present volume fully equals those that have already appeared. Beginning with an account of the position of zinc in industry, a brief notice is given of the history of the metallurgy, after which chapters follow devoted to the purely practical side of the subject. These are: Rise and Progress of the Production of Zinc, Zinc Ores and Sources of Supply, Marketing, Furnace Production, Other Methods of Production, Properties of Zinc, Marketing and Industrial Applications of it and its Alloys, Commercial Products, including Zinc Pigments. The text of the work closes with a chapter on the future of the zinc industry in Great Britain and a bibliography.

The work is a valuable and useful contribution to the literature of an important phase of metallurgy. Aside from this, the following quotations from the Introduction will prove interesting to the American reader: "Before the war, the world's markets for the majority of non-ferrous metals were very largely controlled by a group of German metal companies, engaged primarily in buying metals and acting as selling agents for the producers. How complete this control was few people knew * * * * The most important of these concerns was the Metallgesellschaft of Frankfort-a-M. * * * * This control was a source of great embarrassment to the British Government at the outbreak of the war." With a view of preventing such control in the future, the British Parliament passed "The Non-Ferrous Metals bill," designed to keep the control of the essential metals in British hands. Before the war the bulk of the zinc used in England was obtained from Germany and Belgium. Both countries were large producers of the metal, and large importers of ore from the most important mine in the British Empire, that at Broken Hill, Australia. The outbreak of the war led to a remarkable situation in British and Colonial markets, owing to the cutting off of supplies of the metal, and the loss to Australia of nearly all its markets for zinc concentrates. While there were enormous quantities of zinc ore awaiting

shipment in New South Wales, most British smelters were unable to treat it, as their furnaces were not adapted to that class of ore. This shortage was partly met by importations from the United States, but notwithstanding this, the price rose enormously.

It is partly with a view of rendering England independent of Germany in the matter of zinc production that this work has been prepared. We wish it success. HENRY LEFFMANN.

TNT. TRINITROTOLUENES AND MONO- AND DINITROTOLUENES: THEIR MANUFACTURE AND PROPERTIES. By G. Carlton Smith, B.S. New York. D. Van Nostrand Company, 1918. 123 pages, contents and index, 12mo. Price, $2 net.

The symmetric trinitrotoluene has become the chief explosive in war. It owes this position to its high shattering power. comparative safety, and as compared with picric acid—its nearest derivative—freedom from action on metals. Picric acid, containing a molecule of hydroxyl, readily ionizes with the production of an acid ion, which in addition to the corrosion that it may cause, produces metallic picrates that easily explode by friction or percussion, so that in time the acid becomes very unsafe. Six trinitrotoluenes can be obtained, but the processes now employed give almost entirely the symmetric (1-2-4-6) form, which is the only one now used.

The present work is devoted for the most part—as might be expected—to the chemistry and properties of the important form, though much information is given as to the accessory products. Beginning with a brief introduction and history of toluene and its nitro-derivatives, the theoretical principles relating to the nitrotoluenes are explained, after which the manufacture and purification of TNT are described. The inspection and testing are described, and also the properties of the series of trinitro-derivatives and of the mono- and dinitro forms. Two interesting chapters are those on accidents and diseases due to the manufacture of these substances. A very large proportion of the disagreeable features of such manufacture is due to carelessness of workers. Without doubt, illicit smoking has caused many disastrous explosions, and uncleanliness many cases of disease.

The work is a useful and concise account of the character and manufacture of a most important war-product.

The canons of criticism will not be observed if attention is not called to some blemishes. The literary style is often far from commendable, and typographic errors are quite numerous. The bibliography, especially, shows very careless proofreading. The misspelling "Anallen" occurs eleven times, "Jahres Berichte" (for "Jahresbericht") twice, "Proc. K. Accad. Metensch" (for "Ver. K. Ak. Wetensch") twice. Four allusions are made to the "London Chemical Society." If there is such a society—which the reviewer doubts—it is not the one intended, but the famous British organization, which is simply the "Chemical Society," without indication of locality or nationality. The reference "1st Scienze Let." will puzzle many. The publication intended is "Memorie del R. Istituto Lombardo di Scienze e Lettere" and should be abbreviated "Mem. Ist Lomb."

The bibliography appears to be in some confusion. Seventeen numbered references are given in Chapter vii, but only eleven are entered in the bibliography list for that chapter. When bibliographic references are made in a list at the end of the work—which is probably the best way—they should be numbered consecutively and not by chapters.

The book is timely, contains much information for the practical worker, and will be likely to find a rapid sale. When a new edition is called for, care should be taken to remedy the errors in grammar and spelling, avoiding such phrases as "The color of the solutions are different" and such misspellings as "assymetry." For the errors here enumerated, and for many others of similar types, the publisher must share responsibility with the author.

HENRY LEFFMANN.

CHEMICAL COMBINATION AMONG METALS. By Michele Giua and Clara Giua-Lollini, translated by Gilbert Wooding Robinson. Philadelphia, P. Blakiston's Son and Company, 1918. 332 pages, contents, indexes and bibliographies, 206 illustrations. 8vo. Price, $4.50 net.

The senior author is professor of general chemistry in the Royal University of Sassari; the junior author was awarded the Cagnola prize by the Royal Lombardy Institute of Science and Literature.

The work is a highly scientific and thorough discussion of alloys, especially of binary systems. The physical chemistry is explained, of course on the basis of the phase rule, and the conditions illustrated by numerous diagrams. The translator has done his work well, and the publisher and printer are also to be highly commended. The authors are to be praised for the care taken in the references to the literature of the subject, as year, volume and page are given. It should be an absolute rule in references to give the year. A list of publications cited, with the abbreviations used, is given. In this are to be noted a few typographic errors, such as "Liebigs" (instead of "Liebig's"), "Deutsche-Reiche-Patent," "Werhandlungen," "Compts rendus," but these are not misleading.

A summary of the chapter-headings will give an idea of the scope of the work: Equilibrium Diagrams; Thermal Analysis; The Nature of Intermetallic Compounds; Physical Properties; Homopolar Intermetallic Compounds; Heteropolar Intermetallic Compounds; Ternary Intermetallic Compounds. A series of tables and indexes of authors and binary compounds close the book. There is no index of the subject-matter in detail. The chapter on "Heteropolar Intermetallic Compounds" is a discussion of the compounds formed between what are commonly called "metals" and the elements often called "metalloids"; that is, carbon, silicon, boron, phosphorus, arsenic, sulphur, selenium and tellurium. The compounds of antimony and bismuth are treated under the "homopolar" section. It is rather startling to the gray-haired chemist to find calcium silicide and cuprous sulphide described in a work on alloys.

The book is a valuable contribution to the literature of metallurgy.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Airplane Characteristics: A systematic introduction for flyer and student and for all who are interested in aviation, by Frederick Bedell, Ph. D., professor in physics, Cornell University. 123 pages, illustrations, 8vo. First edition. Ithaca, N. Y., Taylor and Company, 1918. Price, $1.60 net.

U. S. Bureau of Mines: Bulletin 127. Gold dredging in the United States, by Charles Janin. 226 pages, illustrations, plates, 8vo. Technical paper 195. The tars distilled from bituminous coal in hand-fired furnaces, by S. H. Katz. 20 pages, illustrations, plates, 8vo. Technical paper 205. Saving coal in boiler plants, by Henry Kreisinger. 24 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

American Glass Trade Directory of Glass Companies in the United States and Canada: Compiled by H. W. Gauding, of *The Glassworker.* Vest-pocket edition. 90 pages, 24mo. Pittsburgh, Pa., Commoner Publishing Company, 1918. Price, $2.

Trade Directory, containing list of pottery, glass, lamp, enamel and aluminum ware companies, also manufacturers' and workers' organizations: Compiled by Henry W. Gauding. Vest-pocket edition. 74 pages, 24mo. Pittsburgh, Pa., China, Glass and Lamps, 1918.

U. S. Tariff Commission: Tariff information, series No. 6. Census of dyes and coal-tar chemicals, 1917. 73 pages, 8vo. Washington, Government Printing Office, 1918.

New Treatment for Sulphur. ANON. (*Engineering and Mining Journal,* vol. 106, no. 15, p. 657, October 12, 1918.)—Recovery of native sulphur from rock mixtures with which it occurs in several Western regions is one of the problems calling for solution because of the increased war demand for sulphur and the consequent attempts to operate deposits of native sulphur in West Texas, Idaho, Wyoming, and Nevada. The liquation method, which has been practiced solely heretofore, involves relatively costly installations; the operation is expensive under the usually prevailing fuel conditions, and the recovery of sulphur has been low. Liquation plants have been operated in Wyoming and Nevada, and recently two were installed in the West Texas sulphur district.

About a year ago the engineers for Minerals Separation Company made tests for the purpose of demonstrating that the flotation method was applicable to the separation of native sulphur, and at about the same time Kirby Thomas, of New York, conducted a series of experiments which indicated that the recovery of sulphur by flotation methods was commercially feasible and presented advantages over the liquation operation. The data were subsequently presented to the Bureau of Mines, at Washington, and the Bureau arranged with James A. Hyde, of San Francisco, to make a complete and adequate series of tests. This work is now being done, and the results are reported to be satisfactory. The flotation process permits of the treatment of fines and of sulphur-bearing material not adaptable to the liquation method. The West Texas Sulphur Company, of Culbertson County, Texas, is planning to install flotation equipment as soon as the results of the Government tests are made available.

CURRENT TOPICS.

Adapting 220-volt Circuits to 110-volt Lamps. J. R. CALVILLE. (*Electrical World*, vol. 70, No. 25, p. 1189, December 22, 1917.)—It is a matter of common knowledge that incandescent lamps which are rated at 110 volts or 125 volts are more satisfactory that those designed for 220 volts or 250 volts. Lamps designed for the lower-voltage range are more efficient, give a more satisfactory life performance, and are lower in price than the higher-voltage units, for the reason that the higher voltages are nearer the upper limit at which it is possible to manufacture incandescent lamps that will be commercially satisfactory. Notwithstanding these facts and that there are simple expedients, such as the installation of a balancer coil or a motor-generator set, whereby most installation using 220- to 250-volt circuits can be changed over so as to use 110- to 125-volt lamps, there are still many of the higher voltage in use. The difference in cost between lamps of the 110- to 125-volt class and those of the 220- to 250-volt class ranges from about 4 cents per lamp for the smaller lamps when purchased on large contracts to as much as $1.40 when the largest lamps are purchased at list price. The higher-voltage lamps also give only about 90 per cent. of the light which corresponding sizes of the lower-voltage lamps give. Hence, for equal illumination intensities more voltage is required with the 220- to 250-volt lamps.

In the design of new installations the number of units which may be used advantageously is sometimes closely limited by the constructional features of the building. In such cases, 220- to 250-volt lamps of higher wattage, and frequently the purchase of more expensive reflector equipment, are required. On the other hand, if considerable latitude in the location of the units is afforded, a greater number of the higher-voltage lamps of a given wattage will have to be installed to obtain the same degree of illumination as might be obtained with the 110- to 125-volt lamps. This will entail the installation of more outlets, the purchase of a greater number of reflectors, sockets, etc., and a heavier maintenance expense. The difference in cost of lamps of the two voltages, together with the fact that fewer 110- to 125-volt units are required—that is, the difference in first cost of the installation—is often of sufficient magnitude to pay for the installation of equipment to provide the lower voltage for the lighting circuit. The yearly saving in lamp renewals and energy is then pure profit.

The Magnetic Permeability of Steel. F. P. FAHY. (*Chemical and Metallurgical Engineering*, vol. 19, No. 5, September 1, 1918.)—The information to be derived from the normal induction and hysteresis data is of the first importance in the selection of material intended for use in the construction of electric machinery or ap-

paratus which depends for its efficient operation upon the magnetic characteristics of some component part. Sometimes material of high permeability and low hysteresis is required, as in generators, motors and transformers. On the other hand, permanent magnet material must have opposite characteristics.

The question of the magnetic characteristics of iron and steel, and necessarily the methods of measuring such characteristics, is one of importance to metallurgists and chemists. The signal improvement in recent years in the magnetic quality of transformer steels is the happy result of skilled chemical and metallurgical treatment. The more recent work of Yensen on electrolytic iron melted in vacuo, when translated into practice will mean greatly increased operating efficiency in many forms of electrical apparatus. The magnetic characteristics of this exceptional material may be modified by variations in chemical content so as to adapt the material to special operating conditions.

At the present time particular attention is being given to research work on permanent magnet material. There are several reasons for this. First and foremost is the enormously increased demand for magnet steels. Again, a short time ago, the scarcity and price of tungsten led to further investigation in the matter of substituting chromium as the preponderating alloying element. Chrome magnet steels were not unknown, but the action of tungsten being apparently more favorable to the attainment of the desired magnetic characteristics, the use of such steels was limited. While magnet steels of good characteristics are readily procurable to-day, it is a fact that development in this direction has lagged to such a degree that there is opportunity for very considerable improvement.

Material intended for permanent magnet steels is practically always used in the heat-treated condition. Sometimes the steel after hardening is subjected to thermal or jarring aging processes. The residual induction when the magnetizing force is removed, and the coercive force or magnetization required to reduce the induction to zero, both should be as high as possible in value for a material intended for use in permanent magnets. Coercive force, besides being of value in overcoming demagnetizing influence, is also of assistance in counteracting the effects of severe vibrations to which magnets are frequently subjected.

While standard tests of permanent magnet material are made under conditions where the magnetic circuit is closed upon itself, corrections being made for its influence of joints in the circuit, magnets themselves are usually employed under circumstances where the magnetic circuit is open. An instance may be found in the case of a magneto. Here the circuit is made up of the magnet, two air-gaps and the armature core. The open circuit modifies in an important manner the induction designated as residual induction for the reason that the poles of the magnet exert a demagnetizing influ-

ence on the magnet itself which reduces the induction. A new term, namely, remanent induction, must be considered. Remanent induction is to the open magnetic circuit what residual induction is to the closed magnetic circuit. It is the remanent induction which determines the strength of the magnet under the conditions in which it is to be used.

The practical usefulness of magnetic data has been greatly augmented by the proof that they furnish valuable information as to the mechanical properties and structural characteristics of those materials which are magnetic in character, as iron and steel. The limitations of the microscope and the fact that hardness and chemical tests frequently fail to distinguish between materials, while the magnetic test shows distinct differences, greatly augments the serviceability of this new addition to metallurgical test procedure. Comparatively great magnetic changes accompany thermal or mechanical treatment.

The Oxide Film Lightning Arrester. C. P. STEINMETZ. (*General Electric Review*, vol. 21, No. 9, September, 1918.)—The practical experience of the last ten years has proven the aluminum cell arrester the only type capable of affording protection in modern high-power circuits. It has proven this so conclusively as to lead to its universal adoption in such circuits, despite the inconveniences incident to the need of daily attention in charging, the use of a liquid electrolyte, and the difficulty of testing the arrester without taking it apart, except by watching the appearance of the charging arc or measuring the charging current.

The oxide film lightning arrester represents a new type of lightning arrester which has all the characteristics and advantages of the aluminum cell arrester but does not require any charging, and thus requires no special attention. It contains no liquid electrolyte, no inflammable material, and like the aluminum cell arrester can be located out-doors as well as in-doors.

The cell of the oxide film arrester consists of two circular metal plates as electrodes, which are kept apart by a porcelain ring. The space between the electrodes inside of the porcelain ring is filled with the active material, lead peroxide, $Pb\,O_2$, which is packed in under moderate pressure. This active material is a good conductor, but has the characteristic that the action of an electric discharge converts it, in the path of the discharge, into a lower oxide which is an insulator. Thus when an alternating current is passed through such a cell, the active material at the electrodes gradually converts into a non-conductor, and forms a thin insulating film at the electrode. This grows in thickness until it cuts off the further flow of current and holds back the voltage, about 250 to 300 volts per cell. Then only a small leakage current of a few milliamperes passes at normal voltage, but if an over-voltage of any kind appears at the cell, the insulating film of lead oxide punctures and freely discharges through the lead peroxide in the path of the discharge into the

lower non-conducting oxide, and closes the puncture holes, repairs or reseals the film.

A number of such cells, depending on the voltage of the circuit, are piled up on top of each other with a spark-gap in series. The need of this spark-gap in series with the arrester is the only still remaining undesirable feature which the oxide film arrester shares with the aluminum cell arrester, the multi-gap arrester, and other types.

Tall Chimneys in Metallurgical Plants. ANON. (*Engineering and Mining Journal*, vol. 106, No. 4, p. 168, July 27, 1918).—Tall chimneys are erected to achieve a definite result and not, as is sometimes thought, to satisfy a whim to produce spectacular effect. Apart from producing the necessary draft for the satisfactory burning of fuel, a chimney has two main functions: it removes and disseminates the waste products of combustion at a sufficient height to obviate or minimize danger or discomfort to individuals, or damage to crops.

The tallest stack in existence is that of the Tacoma Smelting Company at Tacoma, Washington, which was placed in operation in the beginning of March, 1918. The shell is built of paving brick on a concrete footing. It is 572 feet, 10 inches high, and 23 feet, 11 inches inside diameter at the top, and 38 feet 11 inches inside the lining at the base; the outside diameter of the stack shell at the base is 50 feet, 2 inches. The brick shell ranges in thickness from 5 feet, 1 inch at the base to 13½ inches just below the bell at the top. The stack has a 4-inch sectional firebrick lining, separated from the shell by a 2-inch air space.

The record for height was previously held by the reinforced-concrete chimney at Saganoseki, Japan, for the copper smeltery; it is still the highest reinforced-concrete chimney. According to the builders, the Weber Chimney Company, the Japanese stack is 570 feet high, 42 feet, 8 inches outside diameter at the base, and 26 feet, 3 inches inside diameter at the top.

Among other high chimneys may be mentioned those of the Anaconda Mining Company at Anaconda, Montana, 525 feet high and 60 feet in diameter; and at Great Falls, Montana, 506 feet high and 50 feet in diameter. These are of perforated radial brick, built by the Alphons Custodis Chimney Construction Company.

Abrasives. FRANK J. KATZ (*U. S. Geological Survey*).—*Emery and Corundum.*—During the first half of 1918 emery ore was produced by seven operators in the Peekskill district, in New York, and by one in southern Virginia. Corundum is produced from one mine in Macon County, N. C., and by one company operating in Renfrew County, Ontario. The combined mine output of emery and corundum in the United States and Canada from January 1 to June 30, 1918, was 5455 short tons. During the same period the producers sold, shipped, or used in the manufacture of abrasive articles approximately 4500 short tons, and the stock on hand at the mines June

30 was about 1500 short tons. As compared with the same period in 1917, there was a large decrease in the quantity of emery mined, and the output from January to June, 1918, inclusive, was considerably less than half of the mine output of emery for the entire year 1917. During the first half of 1918 corundum was produced at about the same rate as in 1917.

Artificial Abrasives.—Artificial carbide abrasives, including carborundum, crystolon, and carbolon, were produced during the first half of the year 1918 by two companies in the United States, operating plants at Niagara Falls, N. Y., and at Blasdell, N. Y., and by three in Canada, operating plants at Shawinigan Falls, Quebec, and at Chippewa and Thorold, Ontario. The plant output of crude carbide abrasives was 6583 short tons. During the same period the producers sold or used in the manufacture of abrasive materials 5633 tons, and on June 30 there remained in their hands as stocks 2840 tons.

Aluminum, oxide abrasives, including alundum, aloxite, exolon, lionite, and natite, were manufactured in the United States by four companies, three of which operated plants at Niagara Falls, N. Y., and one at Blasdell, N. Y., and in Canada by five companies, which operated plants at Niagara Falls, Chippewa, and Thorold, and two at Hamilton, Ontario. The combined output of these plants in the first half of 1918 was 28,341 short tons. During the same period the producers sold or used in the manufacture of abrasive materials 28,161 short tons, and on June 30 there remained in their hands 26,221 short tons. The combined figures for carbide and alumina abrasives for the first half of 1918 are: Manufactured, 34,974 short tons; material sold or used, 33,794 short tons; and stock in hands of producers June 30, 29,061 short tons. As compared with the first half of 1917, there was an increase in production of nearly 60 per cent. The production in the first half of 1918 was approximately equal to 62 per cent of that for the whole year 1917.

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